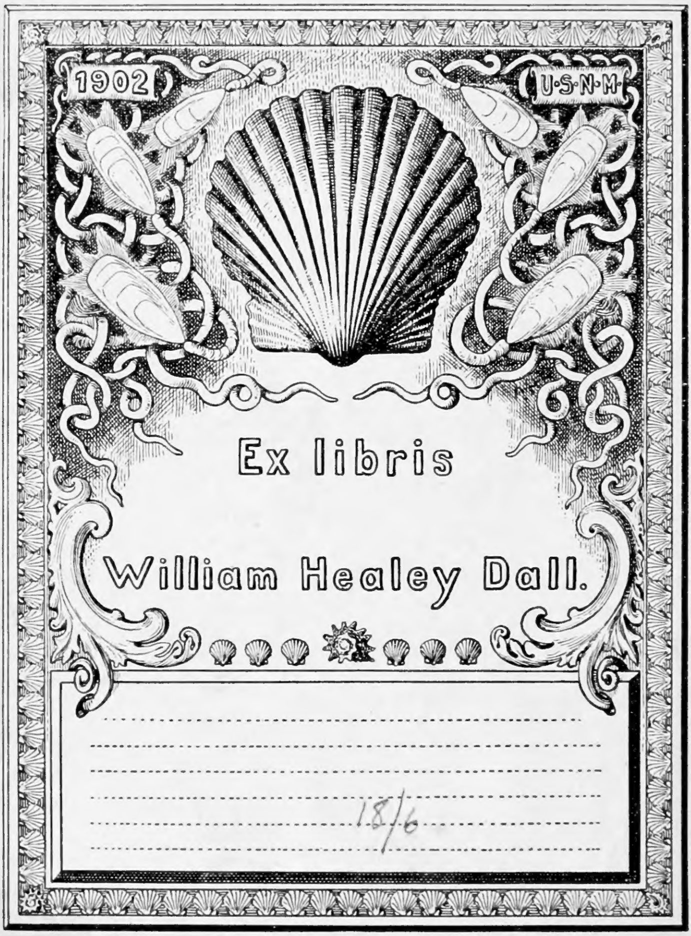
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REPORTS

OF THE

FIRST, SECOND, AND THIRD MEETINGS

OF THE

ASSOCIATION

OF

AMERICAN GEOLOGISTS AND NATURALISTS,

AT

PHILADELPHIA, IN 1840 AND 1841, AND
AT BOSTON IN 1842.

EMBRACING ITS

PROCEEDINGS AND TRANSACTIONS.

BOSTON:
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1843.

COMMITTEE ON PUBLICATION.

HENRY D. ROGERS,
LEWIS C. BECK,
B. SILLIMAN, JR.,
AMOS BINNEY,
AUGUSTUS A. GOULD.

SAMUEL N. DICKINSON, PRINTER.
52, Washington Street, Boston,

THE ASSOCIATION

OF

AMERICAN GEOLOGISTS AND NATURALISTS

GRATEFULLY

DEDICATES THIS VOLUME

TO THE

HON. NATHAN APPLETON,

OF BOSTON,

TO WHOSE MUNIFICENCE AND ACTIVITY THE CULTIVATORS OF SCIENCE

ARE MAINLY INDEBTED

FOR ITS PUBLICATION.

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PREFACE.

Besides the Papers read at the three meetings heretofore held, the present volume includes an account of the proceedings of the Association of American Geologists and Naturalists, from its origin. It affords, therefore, a view not merely of the past labors of the Association, but of its plan and objects, which, it will be observed, differ essentially from those proposed by the other scientific societies of this country. Aiming to promote a closer intercourse between the numerous cultivators of Geology and Natural History throughout the United States, and to lend greater efficiency, by systematic coöperation, to the active exertions now making in these departments of Science, it has imitated in its essential features those Associations of other countries which are seeking, in their several spheres, similar results. It cannot, however, pretend, in the present early stage of its progress, to copy the full and effective organization of some of its distinguished European prototypes. The transactions of the Association have hitherto been confined chiefly to communications, written and oral, of individual members, and to the discussions which these have suggested. It is, however, within the plan of the Society, to procure reports from committees, and individual members, on special subjects of research, several of which have been undertaken, and also on the progress of particular branches.

The annually increasing store of written contributions from members, besides these reviews of the state and progress of certain departments of inquiry, will, it is believed, soon call for the publication of another volume.

The miscellaneous oral communications on various questions of science, and the very interesting and instructive discussions to which these and the more elaborate written ones, gave rise, though imparting a high zest to the proceedings of the meetings, are necessarily but imperfectly reported in these pages.

Sincere thanks are due, by the Association and the friends of science throughout the country, to those gentlemen of Boston, who, with characteristic liberality, have contributed very important pecuniary aid towards the publication of the present volume, which, but for their opportune assistance, could not have appeared. The numerous lithographic illustrations, which so materially enhance the utility of the volume, required too considerable an outlay for a Society still young, and limited in numbers.

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PROCEEDINGS OF THE ASSOCIATION

OF

AMERICAN GEOLOGISTS AND NATURALISTS.

FIRST SESSION. 1840.

At a meeting held at the rooms of the Franklin Institute in the city of Philadelphia, on the 2d of April, 1840, the following gentlemen were present, namely:

Edward Hitchcock, Amherst, Mass.; Lewis C. Beck, New Brunswick, N. J.; Henry D. Rogers, Philadelphia; Lardner Vanuxem, Bristol, Pa.; William W. Mather, Brooklyn, Ct.; Walter R. Johnson and Timothy A. Conrad, Philadelphia; Ebenezer Emmons and James Hall, Albany, N. Y.; Charles B. Trego, James C. Booth, M. H. Boyé, R. E. Rogers and Alexander McKinley, Philadelphia; C. B. Hayden, Smithfield, Va.; Richard C. Taylor, Philadelphia; Douglass Houghton and Bela Hubbard, Detroit, Michigan.

Prof. Hitchcock was appointed Chairman, and
Prof. L. C. Beck, Secretary.

It was then unanimously resolved to organize an Association, to be called "The Association of American Geologists."

After the transaction of business relating to the election of additional members, the time and place for holding the next annual meeting, &c., several communications were made to the Association, and discussions had thereon. The following is a brief abstract of these proceedings.

April 2d. — Specimens were laid on the table, of quartz, phosphate and carbonate of lime, having a fused appearance, occurring in St. Lawrence county, N. Y.; and some views were offered concerning the causes which have given rise to it. Remarks having been made on this subject by other members, it was referred for a full report at the next meeting of the Association.

Specimens were next presented of the sandstones of Massachusetts, exhibiting the fossil footmarks, so called, and observations made in regard to them. This subject was of so much interest as to induce the Association to appoint a committee to visit the localities, and to report their conclusions at the next meeting.

After this, followed a discussion on the subject of diluvial action, in which several members took part. Information was communicated concerning the diluvial grooves or scratches, which are observed in the valleys of the Hudson, Ohio, and Mississippi, the polished limestones of Western New York, the erratic blocks found in New York, Pennsylvania, &c.; and several points were suggested for future investigation.

April 3d. — The first business was, a lecture on some parts of the geology of the State of New Jersey. Upon this, remarks were offered by several members; after which there was presented to the Association, an outline of the geology of the State of Michigan. The remaining part of the day was spent in free conversation on various geological topics.

April 4th. — The meeting was opened by some remarks on the apparent stratification of serpentine. A locality was referred to in the State of Pennsylvania, where that rock exhibits the appearance of being regularly stratified. Several members presented facts respecting other localities bearing upon the question of the origin, whether strictly intrusive or metamorphic, of certain belts of serpentine.

A statement was made in regard to the frequent occurrence of fossil infusoria in almost every town in New England in which primary rocks prevail. A member observed, that after the most diligent search, he had been unable to detect them in the cretaceous group. After remarks by several other members, the conclusion was, that so far as fossil infusoria are known in this country, they are confined to the primary formations.

A notice was next presented of the occurrence of the native black peroxide of copper, on the shores of Lake Superior. This was followed by remarks upon the copper ores of New Jersey.

Some observations were then made regarding the coal-fields of Pennsylvania, particularly with reference to certain changes in the chemical composition of the coal as we proceed from the east to the west. Statements corroborating the general correctness of the views presented, and extending the same to the States of Ohio and Illinois, were made by other members.

Some suggestions were next offered concerning the fertilizing properties of mica. These led to some remarks on the cause of the fertilizing powers of the green sand, the peroxide of iron, &c., when it was

Resolved, That the subject of mineral manures be open for discussion at the next meeting, and that the members be requested to note all such facts as may contribute to its elucidation.

Professor Silliman was then unanimously elected Chairman for the next meeting, and the present chairman was requested to open that meeting with an address.

The Secretary was requested to prepare an abstract of the proceedings of this session of the Association, for publication in the American Journal of Science, and in the Journal of the Franklin Institute; when, after the usual vote of thanks, the Association adjourned to meet in Philadelphia on the first Monday in April, 1841.

SECOND SESSION. 1841.

THE second annual meeting of the Association was held during the second week in April, at the rooms of the Academy of Natural Sciences in Philadelphia.

Monday, April 5th, 1841, 4 o'clock, P. M. — The Association met pursuant to the adjournment of last year. The regularly appointed presiding officers being absent, Prof. HENRY D. ROGERS was called to the chair. After the completion of some business arrangements, the Association adjourned until 10 o'clock, A. M. of Tuesday.

Tuesday, April 6th, 1841, 10 o'clock, A. M. — The Association met pursuant to adjournment. Prof. SILLIMAN took the chair. Dr. L. C. BECK was appointed Secretary. Messrs. W. R. JOHNSON, VANUXEM, H. D. ROGERS, MATHER, and LOCKE, were appointed a committee to report a plan of business for the meeting.

The subject of mineral manures having been deferred at the last annual meeting, was proposed for discussion. Remarks were offered, and facts stated by Mr. MARTIN H. BOYE, Drs. CHARLES T. JACKSON, JAMES B. ROGERS, J. LOCKE, and Mr. B. SILLIMAN, JR.

Mr. BOYE inquired whether the antacid powers of magnesia, and its effects on vegetation, had been noticed, as it exists in the dolomitic limestone.

Dr. JACKSON inferred from his observations, that magnesia is injurious only when used in a caustic state, in the same manner as caustic lime is known to be injurious to vegetation by abstracting carbonic acid from the atmosphere, and from decomposing vegetable and animal matters. It also acts unfavorably in virtue of its hydraulic power; rendering, in some cases, the soil very hard. He further stated, that when composted with peat and swamp muck it gained from these substances phosphoric acid, and thus became the means of conveying to wheat and other cereal grains the phosphate of magnesia, known to be always found in their ashes. Dr. JACKSON further considered the combinations of lime with the organic acids of soils as deserving much attention. He had found sub-soils to contain a larger quantity of crenates of lime than the soil, and that some streams in like manner contained a larger proportion of soluble crenates than others; and these former are most valuable for the purposes of irrigation. Dr. J. recommends the employment of a compost of lime, swamp muck or peat, and animal manure; and he attributes the beneficial effect of this in part to the evolution of ammonia consequent upon the decomposition of the organic matters.

The discussion then turned on the character of hydrated peroxide of iron on vegetation. It was thought by Dr. JACKSON, that the injurious effects sometimes known to arise from it were to be attributed to free sulphuric acid contained in it from the decomposition of sulphuret of iron. A marl was cited which at first produced very luxuriant vegetation, but at a subsequent period was found to destroy the plants growing where it had been used, owing to the decomposition of sulphuret of iron contained in it, producing free sulphuric acid, which corroded the plants. Prof. H. D. ROGERS, thought that some of the marls of New Jersey, contained so much sulphuret of iron as to require more alkaline matter than was to be found in them to neutralize the acid resulting from their decomposition. Still it was thought that *small quantities* of sulphuret of iron, in a marl, would by its decomposition be useful in agriculture.

The subject of potash in soils was next brought before the meeting. Dr. JACKSON inquired if any experiments had been made on this subject by gentlemen present. He had digested soils from Maine, New Hampshire and Rhode Island, with boiling water, without discovering more than a trace of potash; while the method proposed by Mitscherlich of digesting the soils in free sulphuric acid, always gave decided indications of potash. He was led to infer, therefore, that the mica and other minerals containing potassa were by this method decomposed.

Mr. B. Silliman, Jr. stated that the soil of the Nile, when treated according to the method of Mitscherlich, gave abundance of potash, but not any appreciable quantity with boiling water; he was therefore led to believe that the mica, contained abundantly in the soil, was decomposed by the sulphuric acid.

Resolved, That a committee be appointed to prepare a detailed report upon the subject of soils and mineral manures, imbodying as well the fruits of their own investigations as the results arrived at by others, and that the same be presented at the next meeting.

Drs. C. T. Jackson, Robert Rogers, Mr. M. H. Boye, Dr. L. C. Beck, Dr. W. Horton, Mr. B. Silliman, Jun., and Prof. Booth, were appointed on the above committee.

The committee appointed to prepare a plan of business, made a report, which was adopted.

Prof. Mather asked for and obtained leave to defer his report on "Drift," until the next meeting of the Association; in the mean time he was requested to make an oral communication on this subject during the present meeting.

Prof. Locke read a paper "On the Geology of some parts of the United States west of the Alleghany Mountains."

In this paper the author exhibited particularly the points of agreement between the lead region of the upper Mississippi, and that of Derbyshire in England, and between the mountain limestone of Europe and the "cliff limestone" of the West. He showed that the two rocks agree in geological position, in external and chemical characters, in fossil remains, and in metallic veins; being both highly metalliferous, and abounding in lead and zinc ores occupying vertical fissures. He described the upper, middle, and lower beds of the "cliff limestone" of the lead region of the West as differing somewhat in characters and in fossil remains, and suggested the inquiry whether these three beds, together with the blue fossiliferous limestone which underlies them, (the probable equivalent of the Trenton limestone,) and the alternations of the lower magnesian limestone with the saccharoid sandstone, found at Prairie du Chien, should be considered distinct formations, (as their fossil remains would to some extent indicate,) or as different members of one formation — the mountain limestone.

In reply to some remarks by Prof. H. D. Rogers, Prof. Locke observed, that he did not undertake to be the advocate of absolute equivalency, but merely to point out the agreement and disagreement of certain formations in America with similar ones in Europe. He was of opinion, however, that certain points of equivalency must be admitted, as for example granite, the great coal formations, &c.

Prof. Mather proposed the subject of "Joints of Rocks" for discussion during this session of the Association; and Prof. H. D. Rogers proposed that of "Fossil and Recent Infusoria."

The Association then adjourned until 4 o'clock this afternoon.

April 6th, 1841, 4 o'clock, P. M.—The Association met pursuant to adjournment, Prof. Locke in the chair.

Mr. William C. Redfield exhibited specimens of fossil shells, from the tertiary marl-beds at Washington, Beaufort county, North Carolina.

Mr. R. stated that these beds, which are about sixty miles from the Atlantic, are found from fifteen to twenty feet below the adjacent surface, and two or more feet lower than the usual level of Pamlico river and sound. The fossils are in a good state of preservation, and are supposed to belong to the miocene period.

Prof. Locke read a paper "on a new species of Trilobite, found at Cincinnati, Ohio," and called by him Isotelus maximus.

This species is characterized by its elliptical terminations, and by a thorn-like process about one tenth of the length of the animal, projecting backwards from each angle of the shield, similar to an Ogygia. He exhibited casts of one entire specimen, nine and three fourths inches in length, and of a fragment of another of double that size in linear dimensions, which of course must have been nineteen and a half inches long — the largest specimen hitherto known to have been found.

Dr. Jackson stated that trilobites had been found in the limestone at the mouth of St. Croix river. He then exhibited the following specimens of minerals and fossils, namely:

Fossils from the limestone belonging to the red sandstone group of Machias, Maine. A new mineral from Unity, New-Hampshire, which he has analyzed and proposes to describe under the name of Chlorophyllite. A new mineral from Natick, Rhode Island, described by him under the name of Masonite. Tin ore from Jackson, New Hampshire, near the celebrated Notch of the White Mountains. Sulphuret of copper and iron mixed with tremolite, from the town of Warren, N. H.;

the rock yields from six to twelve per cent. of metallic copper. Recent bituminous coal from the vicinity of Newfield, Maine, taken from a peat bed. New red sandstone from Tobique River, in New Brunswick, containing about one half its weight of gypsum. Syphonia, fossil-like substances with tubuli running through them and assuming various forms. They were supposed to be concretions formed around twigs and roots of trees or other organic matter.

Dr. L. C. Beck read a paper " On the Sulphur Springs of the State of New York."

In this paper the author noticed, 1st. The geographical range of these springs, their geological positions and association. Under this head it was stated that they are found in almost every formation, from the slates of the Hudson river to the shales of Erie and Chatauque county, having a range over nearly the whole state, and being found in almost every county. 2. The amount of gaseous matter evolved by these springs. This cannot be correctly ascertained, but from many facts stated by the author, there can be no doubt of its vast quantity. Some instances were mentioned in which large streams and ponds were impregnated with sulphureted hydrogen. It was also remarked, that independently of the amount of gas which is held in solution by the waters of these springs, there is often a flow of gas which seems to be undissolved or uncombined. 3d. Some facts were stated in regard to the uniformity in the composition of these springs. In all cases in which they have been examined, they contain, in addition to the sulphureted hydrogen, a small proportion of carbonic acid. The solid matters are almost invariably sulphates of lime and magnesia, with smaller proportions of carbonate of lime, and occasionally sulphate of soda. It was especially observed that sulphate of iron is very rarely found among the solid ingredients of these waters. Common salt is often found in the sulphur springs which occur in the vicinity of the Onondaga brine springs. 4th. The author next adverted to the observations which had been made in regard to the temperature of the New-York sulphur springs. Although these have not yet been very extensively conducted, those which have been made seem to warrant the inference that the temperature of these springs is somewhat higher (say 1° to 3°) than that of the mean temperature of the localities in which they are found.

The author then proceeded to examine the theories which have been proposed to account for the formation of sulphur springs. The decomposition of iron pyrites, often assigned as a cause, was objected to on the ground that it was not sufficiently general — that it did not meet those cases in which these springs are found in the older rocks — that from what is known concerning the decomposition of iron pyrites, it seems to be inadequate to account for the enormous quantity of sulphureted hydrogen which is evolved, and lastly, that the almost entire absence of sulphate of iron in the New-York sulphur springs, is irreconcilable with this theory.

The author then noticed the two general theories which have been proposed in regard to the origin of these springs, and gave the preference to the chemical theory, or that which attributes them, as the products of the great volcanic focus, to a chemical agency, as most consistent with the facts hitherto observed in the State of New York. He proposed, however, to extend the chemical theory so as to include the action of water upon the sulphurets of the bases of the alkalies and alkaline earths assumed to exist in the interior of the earth.

The Association then adjourned until 10 o'clock, Wednesday morning.

Wednesday, April 7th, 1841, 10 o'clock, A. M.—The Association met pursuant to adjournment. Prof. SILLIMAN in the chair.

The subject of Sulphur Springs was discussed by Messrs. H. D. ROGERS, LOCKE, M. H. BOYE, JOHNSON and MATHER. Mr. VANUXEM announced his intention of presenting his views in regard to the New-York sulphur springs at the next meeting of the Association.

Prof. HUBBARD presented a specimen of the slate found at Waterville, Maine, containing impressions, which in the Geological Report of Maine, were described as resembling ferns and fuci, which they resembled more than any thing else that had been found at that time, and of course an error in regard to their nature was unavoidable. Having received Murchison's Silurian system about two years since, Prof. H. found that the impressions were true Annelides, and belong to the two genera Myrianites and Nereites, figured in that work; thus carrying the occurrence of organic life in the New England rocks one step lower than had heretofore been observed, and showing a coincidence between the Waterville slate, and the slate containing the Annelides described by Murchison, and included by him among the Cambrian rocks.

Dr. JACKSON observed that he had received information from other gentlemen, that impressions of ferns occurred in the Waterville slate, and had stated this in his first annual report of the geology of Maine. He had, however, subsequently visited the locality and satisfactorily ascertained that the slates of Waterville do not belong to the coal formation, and this fact was stated by him in his second report. Dr. J. remarked, that in justice to the gentlemen referred to, it should be observed that Prof. Sedgwick and Mr. Murchison's Report was not then published, and consequently these fossils could not be identified with the Annelides there described. On seeing this work, Dr. J. had been able so to identify them, and he now concurred in the views expressed concerning them by Prof. Hubbard.

Prof. MATHER stated that he had found an entire analogy in the fossils of the slates on the Hudson river, in Rensselaer and Saratoga counties, and in the western parts of the State.

Mr. VANUXEM confirmed the statements of Mr. Mather in regard to the identity of these slates.

Mr. W. C. REDFIELD made some observations concerning the fossils in the flagging slates employed in the city of New York. These slates are generally obtained from the counties of Greene and Ulster, N. Y. He referred to the corner of Cedar street and Broadway, and to the walk in front of the Spring street church, near the Hudson, as exhibitions of these impressions.

Prof. H. D. ROGERS observed, that the pavement in front of the United States Bank, (Philadelphia,) afforded a similar exhibition.

Dr. JACKSON now offered some general remarks upon the geology of the states of Maine and New Hampshire.

At 12 o'clock the Association adjourned, as a mark of respect to the memory of General Harrison, late President of the United States, whose funeral took place at that hour.

April 7th, 1 o'clock, P. M.—The Association met, Prof. SILLIMAN in the chair. After the transaction of some ordinary business,

Mr. W. C. REDFIELD laid on the table sundry specimens of fossil fishes found in the red sandstone formations of Connecticut, Massachusetts, and New Jersey.

Of eight species from these formations comprised in the collection, five species are found to belong to the genus *Paleoniscus*, and three species to the genus *Catopterus*. It is remarkable that nearly all of these several species are common to most of the known localities of these fossils in the above mentioned states. The importance of this fact, as aiding to establish the contemporaneous character of these formations, induced Mr. R. to place this collection before the Association.

Mr. R. stated that the lithological appearances of the shales in which the fossil fishes are found, as well as of the more minute and undetermined fossils which they contain, are nearly alike in all the localities which he has visited in the above mentioned States. Slight contortions of the strata, with small faults or dislocations, which in some cases affect the fossil specimens, are also common to the several localities, and seem to be referable to like causes.

In addition to the above, Mr. R. also exhibited specimens of a new species of *Catopterus* from the rocks which overlie the coal mines in Chesterfield county, Virginia.

Some remarks upon the elevation of trap dykes were made by the chairman, and Profs. H. D. Rogers, Mather, and Hitchcock. The Association then adjourned until 4 o'clock.

April 7th, 4 o'clock, P. M.—The Association met, Prof. Silliman in the chair.

Mr. Vanuxem, from a committee appointed at the last meeting of the Association, presented a report in regard to the "Ornithichnites or foot-marks of extinct birds in the new red sandstone of Massachusetts and Connecticut," observed and described by Prof. Hitchcock. This report confirms the opinion respecting these appearances now entertained by Prof. Hitchcock.

Report on the Ornithichnites or Foot Marks of Extinct Birds, in the new red Sandstone of Massachusetts and Connecticut, observed and described by Prof. Hitchcock, of Amherst.

The undersigned, forming the committee to whom the subject of the origin of the bird-tracks of Prof. Hitchcock was assigned, beg leave to present the following brief report.

It may be well previously to state, that the object of the meeting in appointing this committee, was founded solely upon the desire to produce, if possible, unanimity of opinion, there being a few of the members who dissented from the views published by Prof. Hitchcock. In our country, the subject, as it undoubtedly ought, had attracted considerable attention. These views had been very favorably received and republished in Europe, and from its great importance to Palæozoic geology, an attempt should be made to settle the question; for were the views of our highly respected member correct, we were made acquainted with the earliest period in which biped animals existed whose foot-marks were analogous to, if not identical with, those of the tread of birds. On the contrary, if wrong, we were presented with another class of facts, which show that certain appearances supposed to belong solely to animal life, were presented by the vegetable kingdom likewise.

We shall now state, in a few words, what we suppose are the general facts upon which Prof. Hitchcock's views were founded, and then the facts of those who assumed the opposite opinion.

The first and most obvious impression upon the mind, on looking at the indentations or marks, is their thin, tripartite form, resembling the tread or foot-mark of those kinds of birds which show three toes, the fourth one being rudimental, and are referable to no other known kind of animal. The tracks or foot-marks in several localities are arranged in a determinate order, like those of a bird or fowl moving in a straight line, the toes or marks in all such cases being alternate; that is, if the right foot be presented on the rock, the left would next follow, and thus right and left in regular succession, sometimes with many repetitions. In other instances, the foot-marks presented no determinate direction or order, as might naturally be supposed of a bird or any other animal having no particular place or object in view.

In all cases where a succession of tracks was observed, there was a uniform correspondence as to size, and considerable regularity as to distance between the tracks. Whatever deviations were observed, they were not greater than might be supposed to take place in animals possessed of voluntary motion.

On some surfaces, not unfrequently one or more different kinds of track were exposed, belonging, as was reasonably conjectured, to different species and genera of ornithichnites.

That the slaty material of the rock showed that the impressing body possessed force or weight, for frequently the thin layers or laminæ were bent downwards for an inch or more, and that the mud of which the slate was formed was of a highly adhesive or tenacious character.

In all cases the foot-marks, or part impressed, was the fixed part of the rock; the part removed when the lower side was turned upwards, showed the cast or what corresponded with the toes or foot. That no trace of any organic matter could be perceived occupying the cavity or mould, the cast or part in relief being in all respects like the material of the rock of which it formed a part.

Finally, that the foot-marks, belonging to a group of rocks which must be considered to have been produced by the same general causes which gave rise to the new red sandstone of Europe, are referable only to that sandstone. This sandstone presents foot-marks in many localities, though comparatively but a few years have elapsed since attention has been called to them. Some of the specimens have reached this country, and had they not, the information is well given by Dr. Buckland in his Bridgewater Treatise. The most remarkable of these foot-marks, are those of the Cheirotherium from the quarries of Hesburg, near Hildburghausen in Saxony, greatly resembling a fleshy human hand. These, in the drawing and in the specimen which we have seen, are alternately right and left. Other foot-marks have been observed by Mr. Linse in the same sandstone, he having made out four species of animals, some of which are conjectured to belong to gigantic Batrachians. Near Dumfries, the foot-marks of animals, probably tortoises, were obtained from the same sandstone, but as yet no tracks like those of New England have been discovered.

The facts, &c. which led to a different conclusion are these. First, that the forms assumed by fucoidal plants were numerous and imitative, some resembling the tail of a rooster, the cauda galli; another, which was like unto a large claw or paw, and which may have been a lusus naturæ, and the two specimens on the table of the Association, which present in relief a distinct tripartite form. These marks, as they all appertain to rocks of great antiquity in comparison with those of New England, it appeared more reasonable to believe that there might be resemblances as perfect, as the fossils with a tripartite character were approximations to the forms in question.

That no trace of organic matter could be discovered by the eye in the greater number of the fucoides. In some, such as the Harlani, they have been seen to be made up of small pebbles, presenting no little difficulty, not as to the manner only in which the organic matter was replaced, the external form being complete, but as to the nature of this material, which could make so definite an impression and preserve its form entire.

There were other facts which showed resemblances, such as that the part in relief was the part removed when the fucoides was attached to the sandstone at its upper part. It may also be stated, that the appendages to the heel of some of the New England tracks, which, it is supposed, might have been caused by a bird whose legs were feathered, but not to a wader, favored their vegetable origin; for the appendages might readily be conceived to be either leaves or radicals, or both.

From a comparative examination of the facts on both sides, your committee unanimously believe, that the evidence entirely favors the views of Prof. Hitchcock, and should regret that a difference had existed, if they did not feel assured it would lead to greater stability of opinion. To liken things to what we know, is the nature of mind. The error from this tendency increases with ignorance, and diminishes as knowledge increases; so that he that knoweth all things, as is self-evident, can commit no error when following this instinct of his being. The discoveries of Prof. Hitchcock were published at a period when the mind of those who embraced the negative side of the subject was preöccupied with the anomalous vegetation with which many of the Silurian rocks of New York abound, and to which, provisionally, the name of fucoides had been given. From this imitative character, and from finding a few specimens presenting a tripartite or trifurcate form, &c., it appeared not only possible but probable, that the impressions from Massachusetts and Connecticut, were with greater propriety referable to fucoidal bodies, than to those to which Prof. Hitchcock had assigned them.

We may here remark how essential it is that truth, or the facts which make manifest any truth, should first be presented to us; so readily is the mind impressed when not preöccupied, and when a strong impression is made, be it ever so false, it is no easy matter to free ourselves from it. From this circumstance we can readily foresee the advantage which future generations will possess over the present, and especially over those of former times. As the progress of knowledge is certain, each day will lessen error and enlarge the domains of truth; and should man be true to his permanent interests, error finally will cease to have existence.

Signed,

HENRY D. ROGERS,
LARDNER VANUXEM,
RICHARD C. TAYLOR,
EBENEZER EMMONS,
T. A. CONRAD.

Mr. VANUXEM read a paper " On the the Ancient Oyster Shell Deposites observed near the Atlantic coast of the United States."

Among the unsettled subjects of geology in our country, is the origin of the deposits of oyster shells, (*Ostrea Virginica,*) observed in many parts of the Atlantic seaboard, of which a few only of those near South Amboy have come under our notice. But the greater number of those of the largest dimensions are in the waters of the Chesapeake. Some of these southern deposits of shells are enormous, covering, it is said, acres of ground, adding no small weight to the truth of that belief that considers them *in situ,* as ancient oyster beds, raised from their original position by the uplifting of our coast, of which the fact of their generally holding, if not a real, an apparent similarity of level, would seem to be ample confirmation. This theory of their being in place, is highly satisfactory, being in accordance with the less modern deposits beneath them, adding one more to the number of elevating movements to which our coast has been subjected, thus mutually confirming each other, making the certainty of these movements sure.

When the nature of their origin was advanced by Mr. Conrad, I confessed a decided bias; for I knew not the facts upon which Mr. Ducatel, the geologist of Maryland, maintained the opposite one. None were known to me adverse to the views of Mr. Conrad, for the history of our country afforded no light that could be recollected, either as to the origin of these oyster shell deposits, or to any extraordinary manifestation of gastronomic power in the aborigines, in respect of this article of diet, which would lead me to infer their existence, and which the magnitude of some of the deposits required.

The eastern shore of Maryland presents many deposits of these oyster shells, until recently, unused and little examined, so far as knowledge has been received this way. Now, as many of the planters in that section of the country are waking from the deep slumber of the past, and turning their attention to the all-important subject of improving their lands by the use of lime, a few of these deposits have become the subject of investigation, furnishing facts, which, were the same discovered elsewhere, would settle the question of their origin, and in favor of the Maryland geologist.

At the mouth of Pickawaxent Creek, about eighty miles below Washington, there is an extensive deposit of oyster shells, at which an establishment has been formed, which, in a few months has converted many thousand bushels of them into lime. Before any excavation of the mass was commenced, I had directed the attention of Mr. Downing — one of the partners concerned — to the doubtful nature of their origin, requesting that all facts tending to throw light upon them should be carefully observed and preserved. When Mr. D. first went into the country, he was in favor of the views of Mr. Conrad; it was only by the examination of the mass at Pickawaxent, of another not remote from that one, and from subsequent observation in the city of Baltimore, showing the amount of shells which there accumulates, that he was assured that their origin was to be referred to man, and not to other or more elementary powers of nature.

The first and most important fact there observed was, that neither he nor any of the hands employed in getting out the shells had been able to find any two valves which fitted each other, excepting in one instance; a waterman having brought the specimen to him. The deposits had the nature of a mass or heap composed of shells whose valves were separated before being thrown together.

That in many parts of the mass, arrow-heads and fragments of pottery have been found in the progress of excavation — these in no wise different from those found in old settlements of the Indians.

That the bottom of the bed is formed of the yellow loam or soil of the country, and that the roots and other parts of the cedar of the country have been met with at the bottom of the bed, showing a growth upon the surface, before the shells were deposited upon it.

That these deposits are at the mouths of the creeks, extending up the creeks, and rarely extending along the river shore, owing, as Mr. Downing conjectures, to the excellent fishing which the creeks furnish, and which would give to those who accumulated the shells, a two-fold advantage.

That the shore is low on that side of the river where they are found, and the recent oyster is in great abundance on that shore, whilst the channel is on the Virginia side, and no deposit of oyster shells existed in that section of the country.

That these deposits are of some comparative antiquity, is to be inferred from the soil which is found upon them, from the existence of an exceedingly old cedar growing upon the top of a mass, and from the silence of history or tradition respecting them.

Against these facts, which show an undoubted human origin for these deposits of oyster shells, there are others cited by Mr. Conrad, which he has made me acquainted with, since this paper was written, which either I had not known or they had escaped my memory, and are equally conclusive as to the opposite opinion. The facts are, that masses exist composed of whole shells, as at Easton, on the eastern shore of Maryland. That in some localities fragments of older fossils are found with them, and which must have been thrown amongst the oysters, by the waves of the estuary, from their position below. And again, that deposits of the shells exist in situations too remote from present oyster beds to have been made by human agency, such as those in Cumberland county, in New Jersey; therefore it would appear that both causes have operated to produce them, and that no single generalization can comply with the requisition of the facts which are presented, leading as they do to a two-fold one from opposite conclusions, one referable to human, the other, to natural causes; and that severally they must be examined in order to ascertain to which of the two causes any given mass is to be referred.*

LARDNER VANUXEM.

Prof. BOOTH stated that his observations upon these deposits had led him to the same conclusion as that which had been arrived at by Mr. Vanuxem, namely, "that they are sometimes referable to human agency, and at others to natural causes." In answer to an inquiry, Prof. B. observed that these shells reduced to powder had been used with great success in the State of Delaware, as a manure. Prof. HITCHCOCK stated that the fertilizing powers of these deposits of shells had also been tested by experiments on Cape Cod. Facts were stated by the chairman and Prof. MATHER in regard to beds of oyster shells similar to those described by Mr. VANUXEM, on the Island of Nantucket, and on Long Island.

Prof. BAILEY commenced his account of "Fossil Infusoria," by an exhibition and description of the microscope employed by him in his researches.

Messrs. CHARLES B. TREGO and B. SILLIMAN, Jun. were appointed assistant secretaries. The Association then adjourned until nine o'clock, Thursday morning.

Third day of meeting, Thursday, April 8, 1841.—The Association met at nine o'clock, A. M. Prof. SILLIMAN in the chair. The minutes of yesterday were read and adopted.

PETER A. BROWNE, Esq. laid on the table, for the inspection of the members, a suite of specimens, chiefly fossils, from the chalk basin of Paris, collected and labelled by A. Brongniart.

Prof. LOCKE made some observations concerning the connection of magnetism with geology, mentioning an instance where he found an increase of the dip and intensity as he approached, from south to north, a certain point or meridian line, and a de-

* Since the meeting of the Association, I have found on conversing with Dr. Ducatel that the impressions which I had of his views were founded upon his first report, that of 1834, for in his subsequent ones, he makes known their two-fold origin. We should withdraw this paper did we not believe that it would be of service; for it not only settles the point in question, which was its object, but it affords a useful lesson as to caution in expressing the opinions of others.

crease as he receded from it; also remarking that a similar change is found upon crossing the Ohio river: querying from this, whether the water of large streams running east and west, has an influence on the magnetic relation.

Dr. Houghton remarked, that in the vicinity of the great northwestern lakes a change in the magnetic deflection was frequently found on approaching within a few miles of a large body of water.

Dr. R. E. Rogers called the attention of the Association to the subject of limestones, observing that he thought the magnesian character of these rocks generally had not received sufficient attention. He stated that he had found, upon analyzing some of the lower limestones of Pennsylvania, a larger proportion of magnesia than is requisite for the formation of a true dolomite, and threw out the query as a point of scientific interest, whether the carbonate of lime and carbonate of magnesia were chemically combined in the proportions to form dolomite, and this mingled throughout the excess of the carbonate which might be present, or whether the two carbonates were mechanically and uniformly intermingled.

Dr. Jackson stated, that he considered the granular or crystallized dolomite to be a regular chemical double salt, consisting of one equivalent of carbonate of lime and one equivalent of carbonate of magnesia. But he had never found any magnesian limestone to contain *more* than this proportion of magnesia, although he had frequently analyzed limestones containing a *less* proportion than one equivalent of magnesia. His published analyses will illustrate this remark.

Dr. J. inquired whether Dr. Rogers had ascertained if the limestones to which he alluded did not contain the hydrate or silicate of magnesia, mixed with dolomite. If the rock was of the compact variety, this might have been the case.

Dr. James Rogers thought we must consider dolomite as a true double salt — 1 atom carbonate of lime + 1 atom carbonate of magnesia; the excess of magnesia found in our limestones must be considered a mechanical mixture.

A communication was received from Peter A. Browne, Esq., expressing a willingness to read before the Association "an Essay on Aërolites, or Meteoric Stones," at the next annual session. Laid upon the table.

Prof. Mather made a verbal communication on the joints in rocks, particularly as they occur in the primary, transition and secondary of this country. He found two principal sets of joints prevailing; the first had a general direction of north by northeast, the second set were nearly perpendicular to the former — besides these, there were two other sets not so well defined. The joints in the primary were not so smooth and well marked as in other formations; this observation was not intended to apply to the joints of slate rocks.

Dr. Jackson cited the joints or fractures of the conglomerate around Boston, and particularly at Roxbury, Mass., and also in the island of Rhode Island, at a place called Purgatory; the large pebbles are broken by these fractures, without dislocation or loosening from their beds. He supposed the parallel and uniform cracks in the lime rocks and slates of Michigan to have connection with the different epochs of irruption of the trap, granite and porphyry.

Dr. Douglass Houghton inquired of Dr. Jackson if these cracks in the conglomerate had reference to the line of bearing, remarking that in Michigan they were nearly at right angles to the line of the longer diameter of the pebbles. Dr. Jackson replied that such was the case in the cases he had cited; that at Purgatory the pebbles were very large, ovate, and arranged with their longer diameters in one direction, seeming to be joined together by very little cement, and yet they were broken at right angles to their longer diameter, without dislocation. He stated that Mr. A. A. Hayes had found that chloride of calcium would concrete pebbles of quartz into a firm mass — this fact might elucidate the present subject. Specular iron was generally observable among the interstices of the pebbles at Purgatory, and more or less of iron and lead ore was generally to be found at the juncture and fissures of the trap dykes.

Prof. Hitchcock thought that the steps of the new red sandstone of the Connecticut valley were the result of the fractures referred to by Prof. Mather — they were nearly coincident with the strike of the strata, as if caused by elevatory movements. He found difficulty in distinguishing between fissures produced by mechanical violence and joints properly so called; he viewed those of the conglomerate as mechanical, those of the slates as chemical. Two cases occurred to him as worthy of notice; the first was of a dyke of greenstone crossed by parallel transverse planes two or three feet apart and at right angles to the strike of the vein. The second case seemed to throw some light on the origin of this class of phenomena; it occurred in a bed of the common blue diluvial clay — the horizontal layers were unmoved, but some of them were divided into double rhombs. The experiments of Mr. Fox, of England, on the lamination of clay by galvanism, seem to explain this structure.

B. Silliman, Jr. had found this rhombic structure in great perfection in the argillaceous sandstone of the Connecticut valley at Hartford, in Connecticut, where this variety of sandstone is used for flag-stone. Many of the joints parallel to this rhombic structure are filled with carbonate of lime.

Dr. C. T. Jackson stated that the great trap dykes of Nova Scotia had the perpendicular columnar structure in a high degree — in the smaller dykes this structure prevails from side to side of the dyke, perpendicular to the walls. He thought that in all cases these phenomena were referable to the way in which the dykes cooled — the structure being perpendicular to the cooling surface; thus the narrow dykes cooled from side to side, and the heavy ones from the upper surface downward.

Prof. Henry D. Rogers remarked, that the trap dykes of Pennsylvania and the magnetic iron ore of New Jersey were abundantly characterized by the columnar structure. He viewed the horizontal columnar structure of the magnetic iron ore, as a very important indication of its igneous origin.

This discussion was here suspended to give an opportunity for Prof. Bailey to read his paper on recent and fossil Infusoria.

Dr. Jackson stated that the mass of infusorial deposit found under peat bogs is hydrate of silica, which loses by being heated to redness from 12 to 15 per cent., principally vegetable matter. Great abundance of this material occurs at Newfield, in Maine, where it covers many hundred acres, and is five or six feet thick. After burning, it is so white and beautiful that it has been fraudulently sold for magnesia alba. The ammonia which is evolved in its destructive distillation, is probably derived from the crenic and apocrenic acids which it contains. Phosphate of lime and manganese are found in it in small quantities. As a fertilizer of land, it is considered of use when containing in large quantity the juices of plants.

A memoir from M. Alexandre Vattemare was presented, proposing a general system of exchange of objects of nature and art among all nations. It was by motion laid on the table.

The subject of bowlders and diluvial scratches was then brought up for discussion by Prof. Mather, and a protracted debate ensued, in which many of the members joined.

Prof. Mather inferred from the facts in the case, that the bowlders and diluvial scratches had, in general, come from the north; those on the east of the Hudson from the northwest, those on the west from the northeast, as by the result of two forces.

The diluvial furrows are, in general, parallel to the valleys in which they are found: thus in the small transverse valleys, the scratches are found parallel to the direction of the valleys, and not coincident with those of the main valleys. All the bowlders seem to have been brought from the northwest, both at the east and beyond the river St. Peter's at the west, and very few are found below 38° or 39° of north latitude.

The chairman (Prof. Silliman) cited the recorded observations of Mr. C. Darwin, naturalist to H. M. ship Beagle, that in South America no bowlders occur nearer the equator than about 40° south latitude.

Prof. Mather had not seen any bowlders in the coal region of Ohio, and very few in Kentucky. He thought that the bowlders mentioned by Mr. Hodge in the gold region of North Carolina, were not transported masses, but were composed of granite which had suffered decomposition *in situ* by atmospheric agency.

Prof. Henry D. Rogers said there was need of much caution in the use of the term bowlder, as regards the size of the mass to which it should be restricted; he was inclined to give the term much latitude. Thus he conceived that a current of drift coming from the north and meeting the terraces of Pennsylvania, would there be arrested and deposit its larger masses — and so from stage to stage, until the onward current would carry forward only the smallest sand; in this way, we may find among the drift of the south, all the materials derived from the northern rocks.

He concluded that all the materials of a current of drift, find their resting place in accordance with gravity.

Prof. Mather doubted whether the large bowlders found on Long Island, resting on beds of sand or fine gravel, could be thus accounted for, because a current of sufficient force to move such large masses would have carried away the sand.

Prof. Rogers replied, that diluvial action could not be restricted to a single epoch.

We must find in secular and periodical elevation, the cause of the translation of the beds of infusorial earth recently found in the tertiary of Virginia, which are there covered by the quiet strata of the Miocene. We have evidence of numerous slight elevatory movements on the eastern coast of North America, and the various terraces of our rivers seem to present the same phenomena; for the source of these elevatory movements we must look to the great volcanic foci of Greenland.

Prof. Locke mentioned a locality in Ohio, at which the limestone is ground down to a perfect plane, as if it had been done by a stone-cutter by grinding one stone on another, over an extent of ten acres. Upon this planished surface, lines have been engraved in systems perfectly straight and parallel, running from northwest to southeast. Some of these lines are fine, as if cut with the point of a diamond, and others perhaps half an inch broad, and one eighth of an inch deep, scaled rough in the bottom, as if they had been ploughed by an iron chisel properly set and carried forward with an irresistible force. Prof. L. inferred from the facts of the exact straightness and parallelism of these lines, that they had been formed by a body of immense weight, moving with a momentum scarcely affected by the resistance offered by the cutting of the grooves. Such a momentum and actions would be supplied by a floating iceberg, whose lower surface should present projecting sharp points of imbedded bowlders.

Prof. Mather further stated, that the bowlders of Ohio were in continuous lines and groups, and not scattered promiscuously. On the river St. Peters, the bowlders may be seen extending for miles, as along a coast line; in some situations one might see them bounding the horizon as far as the eye could reach.

Dr. Locke, in conformity with Prof. Mather's statements, mentioned a region of bowlders in Ohio, extending from the town of Eaton quite across the State; five miles in width and over forty in extent.

Dr. C. T. Jackson remarked, that the phenomena of diluvial currents were well exhibited in the vicinity of Providence, at Cumberland, R. I. A large mass or mountain of porphyritic titaniferous iron, of very peculiar character, exists in that place; to the north of it no bowlders are to be found, but on the south, huge bowlders of it may be seen, and so abundant that the stone walls are built of them; and below, at Papoose Squash Neck, small bowlders of the same characteristic rock are found; south of Newport, and still further south, the same are met with of a smaller size, the whole extending from north to south forty miles, and from six to fifteen in width, diverging to the south.

The characteristic macle rock at Lancaster, Mass., presents similar phenomena, being found in loose masses to the south as far as Bolton, while none can be found to the north of the locality.

He considered the power of the diluvial current greater to the north than at the south, since the evidences of it in Maine are much greater than in Rhode Island; bowlders have been found on Mount Katahdin as high up as four thousand feet; he thought there was no evidence of any elevation of the rocks after the diluvial current had passed.

Mr. NICOLLET proposed, at a future meeting, to make some remarks upon, and to exhibit specimens from, the cretaceous formation on the Upper Missouri.

Mr. REDFIELD expressed a wish that the attention of the Association should, at some convenient time, be called to the recent sand formation along the eastern coast of the United States.

Adjourned to meet this afternoon at 4 o'clock, at the rooms of Mr. RICHARD C. TAYLOR, for the purpose of viewing a model of the coal region of Dauphin and Lebanon counties, east of the Susquehanna.

Thursday, 4 o'clock, P. M. — The Association assembled at the rooms of Mr. Taylor, where that gentleman exhibited a highly interesting model in plaster of the Dauphin and Lebanon Coal region, embracing, altogether, an area of seven hundred and twenty square miles, showing the range of the mountain elevations, with their relative height and position; also their elevation above tide level; the dip of the rocks, the position of the coal seams, and much other useful information.

Mr. TAYLOR accompanied this exhibition with remarks explanatory and statistical, in relation to this coal region, and made some observations on the importance of this mode of exhibiting the geological features of a country, expressing the hope that the day would come when models of this kind, representing the several states, and even the whole United States, shall be constructed. He also enlarged upon the propriety of following, as closely as possible, the actual conformation of the country in drawing sections, and of adopting uniform modes of illustration by colors, &c., and the importance of an equal scale of extension and elevation, as far as practicable in such sections.

Prof. H. D. ROGERS followed with observations upon the Pennsylvania coal formations and the range of their underlying rocks, detailing what he conceived to be the cause of the inverted dip observable along the southern border of the Kittatiny series, ascribing it to a great force acting laterally, and folding and crushing the axes so as to produce this inverted dip by tossing the strata many degrees beyond the perpendicular, and thus producing the present apparent dip of the lower stratified or sedimentary rocks *beneath* the primary.

Adjourned to half-past nine o'clock to-morrow morning.

In the evening, the members of the Association had the pleasure, in common with a number of citizens, of listening to a very interesting and appropriate address from Prof. Hitchcock, embracing all the points at present most interesting to the American geologist.

Fourth day of session, Friday, April 9, 1841. — The Association met, pursuant to adjournment, at half-past nine o'clock, A. M. Prof. SILLIMAN in the chair.

After the minutes of yesterday had been read and adopted, Dr. BECK moved a series of resolutions, of which the first was adopted, as follows:

Resolved, That the thanks of the Association be presented to Professor Hitchcock for the interesting and valuable address delivered last evening; and that a copy of the same be requested for publication.

The committee on business reported the following resolutions, which were all adopted except the first, — it being laid on the table.

Resolved, 1. That the committee recommend to the Association the first Monday of May as the period for the next annual meeting.

2. That the Association adjourn its present annual session this week.

3. That a committee of five be appointed to draft a constitution and by-laws for the regulation of future proceedings of the Association, and that each member of the committee be recommended to draft a plan of organization, to be discussed by the committee.

4. That at each meeting a local committee of three members, resident at the place of the next annual meeting, be appointed, for the purpose of making arrangements for the reception of the Association.

5. That the members of the "Academy of Natural Sciences"

be invited to attend the present session of the Association, and to participate in its proceedings.

Prof. Renwick, Mr. Nuttall, and Dr. Hayden of Baltimore, were recommended as members of the Association.

Dr. Harlan exhibited models of the fossil remains of the *Dinotherium giganteum.*

The first specimen presented to the view of the Association, was the cast of a small model of the *Dinotherium giganteum*, or the great fossil *Tapir* of Cuvier — the only model of the kind, which, as far as Dr. Harlan is aware, has yet reached America. The Paris Garden of Plants possesses a model of the scull, of the size of nature, which is sold by the German naturalists, Messrs. Klipstein and Kaup, for $100. The dimensions of this scull are four feet in length, three feet in width, and two feet in height. In peculiarity of structure and colossal dimensions, the Dinotherium constitutes one of the most curious and interesting animals of an antediluvian Fauna. M. Klipstein, Professor in the University of Giessen, a few years since, discovered a perfectly preserved specimen of the scull on the borders of the Rhine. Baron Cuvier had many years previously described, in his Fossil Animals, some remains of this animal as allied to the genus *Tapir*. The fragments subjected to his observation consisted only of two imperfect pieces of the lower jaw, and some molar teeth. From such data alone, he was able to represent them as belonging to two distinct species, *Dinotherium giganteum* and *D. Cuvieri*, and to estimate the size of the larger species at eighteen Paris feet, which was subsequently proved to be correct. In 1829, Mr. Kaup, director of the museum at Darmstadt, discovered and described numerous portions of this animal, all obtained from the same strata of the tertiary sand of Eppelsheim.

The whole animal creation, fossil or recent, presents no parallel to the structure of the lower jaw and tusks of this animal. The anterior portions are recurved downwards, and from which depend two enormous tusks, in a direction downwards and backwards. The upper jaw is destitute of incisors. The configuration of the anterior nares and their vicinity, demonstrates that the animal was supplied with a *proboscis*, and like the hippopotamus and tapir, the habits of the animal were evidently aquatic; and the peculiar arrangement of the tusks was evidently adapted to the nature of the animal's food and the means of attaining it — they would be very useful in unison with its powerful claws, in eradicating from the mud the thick and succulent roots of aquatic plants, which probably constituted its principal nourishment. A correct notion of the enormous dimensions of this animal may be obtained by a view of the models of the tusk after nature, as well as by a series of the molars of one side of the lower jaw. It evidently attained a size far exceeding that of the hippopotamus of our day.

The last or ungual phalanx, presents so close an analogy to that of the Manis, or scaly ant-eater, that Cuvier, at first sight, referred this species to an animal of that genus, and named it *Manis gigantea.* In offering you my own views of this peculiar specimen of a departed type, it should be stated that various notions exist among different naturalists, as to the real nature and habits of the animal in question. Some German naturalists place it among the *Phocæ.* Blainville took it for a pachydermatous animal, closely allied to the elephant. Kaup considered that it might range as a fifth and last family of the class Edentata. Others referred it to the herbivorous Cetacea, &c. &c.

Dr. H. also made some observations upon the remains formerly described by him as belonging to the "Basilosaurus," but which he is now satisfied, from the microscopic examinations of a section of one of the teeth by Prof. OWEN, should be referred to a genus of the aquatic mammalia, and which is now named "Zygodon," — specimens of the vertebræ of which, from the tertiary deposits of Alabama, he exhibited to the Association.

Mr. NICOLLET then made some highly interesting remarks upon the geology of the region of the Upper Mississippi, and the cretaceous formation of the Upper Missouri.

He referred to his arrival in this country for the purpose of making a scientific tour, and with the view of contributing to the progressive increase of knowledge in the physical geography of North America. After spending several months in Philadelphia, Baltimore and Washington, he proceeded through the southern states; explored the south Alleghany range, the states of South Carolina, Georgia, Kentucky, Mississippi, Alabama, Florida, Louisiana, Arkansas Territory, and Missouri; ascended the Red River, Arkansas River, and to a great distance, the Missouri river. Having thus made himself well acquainted with the lower half of the Mississippi, he undertook the full exploration of that celebrated stream, from its mouth to its very sources; the latter of which he successfully reached near the close of the month of August, 1836. During five years of unremitted exertions, he took occasion to make numerous observations calculated to lay the foundation of the astronomical and physical geography of a large extent of country, and more especially of the great and interesting region between the Falls of St. Anthony and the sources of the Mississippi. With these labors was connected the study of the customs, habits, manners and languages of the several Indian nations, that occupy this vast region of country.

Mr. N. acknowledged, in feeling terms, the generous hospitality, on the part of our citizens generally, of the agents of the American Fur Company, the civil and military officers, as well as the kind protection of the government, extended to him on all occasions, so as greatly to facilitate his operations and second the accomplishment of his designs. At the expiration of this long and arduous journey, Mr. N., broken in health and his means exhausted, returned to Baltimore, where he soon received a flattering invitation from the war department and topographical bureau to repair to Washington. The result of his travels having been made known to these departments and appreciated by them, he was intrusted with the command of a new expedition, to enable him to complete to the greatest advantage of the country, the scheme which he had himself projected in his first visit to the far West; namely, the construction of a map of the region explored by him. This map having been recently submitted to Congress, the senate of the United States has, unanimously, ordered its publication under the direction of the topographical bureau. It is to be accompanied by a report embracing an account of the physical geography of the country represented, together with the most prominent features in the geology and mineral resources of other sections of our western states not embraced within the limits of the map.

Mr. N. then went on to give a succinct account of his geological researches, which, modestly disclaiming any pretensions to be considered a professed geologist, he had felt an irresistible inclination to engage in, as a subject of general and growing interest. This account he offered as a more appropriate theme, in view of the objects contemplated by the present meeting.

Mr. N. said he had traced a magnesian limestone — the cliff limestone of Dr. Owen — which is probably referable to the mountain limestone of European geologists, over a vast extent of country, within the valley of the Mississippi. Connecting his own researches with the facts brought to light in the survey of the Iowa and Wisconsin Territories by Dr. D. D. Owen and Prof. John Locke, and with the observations of Dr. Henry King, during an exploration of the country watered by the Osage river, Mr. N. thought himself warranted in assigning the Falls of St. Anthony on the Mississippi river, as the northern limit of this formation, which to the West, extends to Fort Leavenworth on the Missouri river, and to the South, embraces the metalliferous region of the state of Missouri. This limestone, containing *Trilobites, Catenipora,* and other coralline fossils, is the metalliferous rock not only in Missouri, but in Iowa and Wisconsin, from which the lead and copper ores are extracted. The rock intervening between it and the coal formation is characterized by the occurrence of the *Pentamerus oblongus.* In this relative position, also, are found thin beds of oolitic limestone, that are perhaps referable, geologically, to the oolitic limestone of Tennessee, described by Dr. Troost, who indicates the *Pentremites* as their characteristic fossil; a large number of these fossils, in a loose state, was collected in the vicinity of these rocks. Shallow coal basins frequently occur in Missouri and the south part of Iowa Territory; but on the Mississippi river, the coal disappears, about thirty miles above St. Louis; thence, ascending the river as far as the great Platte river, the cliff limestone and the coal rocks present themselves in alternate succession. In the vicinity of the Platte river, as well as at Council Bluff, a limestone containing *Cyathophylla* of large size, *Encrinites*, and other fossils, appears in a position seemingly between the cliff limestone and the coal. Near the confluence of the Sioux river and the Missouri, there occurs a formation overlaid by a thick deposit of clay, containing, in abundance, several species of *Ammonites* and *Baculites*, *Belemnites*, *Inocerami*, &c. &c., beautifully raised on their exterior and sparry in their interior. Some of them were exhibited to the meeting. These fossils were identified with similar ones belonging to the green sand deposit of New Jersey, a member of the chalk series; but no true chalk or flint (silex pyromage) was observed. The occurrence of this formation had already been indicated, by some fossils that Lewis and Clark and Mr. Thomas Nuttall had brought along with them from their travels, and which were described by Dr. Morton. Mr. N. exhibited further, some fossil bones which had been submitted to the inspection of Dr. Harlan, who describes them as being *vertebræ* of a Squalus and of a nondescript crocodile; also articulated vertebræ of an animal referable to the order *Enalio-sauri* of Conybeare. The surface presented by a transverse section of these vertebræ, Dr. H. thinks peculiar, as also the mode in which the ribs are attached to a small process in the middle of the inferior surface of each vertebra. From their size and unique character, it is quite probable that these vertebræ form a part of the skeleton of the *Sauro-cephalus lanciformis*, (Harlan,) an animal possessing still more of the fish than the lizard, than exists in the organization of the *Ichthyosaurus*, in which respect these vertebræ correspond. According to Dr. Harlan, similar fossils have been found in the green sand of New Jersey and in the chalk of England.

Mr. Nicollet concluded by remarking, that he had followed up and described this formation, along an extent of upwards of four hundred miles, and from information received and from fossils that had been furnished to him, thinks that it extends to the west at least as far as the sources of the rivers Running Water, White, Shayeune, &c. and northwest along the Missouri probably to the Yellow Stone, being an extent in length of about one thousand miles.

Mr. Hodge followed with some observations concerning the secondary and tertiary deposits of the Carolinas, which he intended to imbody in a paper for publication.

Mr. Hodge proceeded to notice the deceptive appearance of the bowlders of quartz and primary rocks, scattered over the country north of Columbia, S. C., and extending throughout the gold region of North Carolina, all *seemingly* referable to a similar cause with that which covered the hills of the northern states with their bowlders. But according to the previously expressed opinions of Messrs. Vanuxem and Mather, these are considered not to have been transported to any distance, but to belong to the rocks in their immediate neighborhood.

He asked attention to the subject of the deposit gold mines; whether these were not still in progress of formation, notwithstanding the opinions to the contrary found in many of the foreign treatises; mentioning their occurrence always near the veins of the ore, and of the fact of veins having been discovered by working the deposits up to them, above which the gold suddenly ceased. Of the power of the freshets, the discovery of the little buried village in Nacochee Valley, Ga., was mentioned as a remarkable evidence. His opinion was, that though many of the deposits referred themselves far back to the period when the whole country was overspread with diluvium, still that the deposits have been going on ever since. Specimens were shown from, and some remarks made concerning, the gold and copper ores of Davidson and Guilford counties, N. C. Veins originally worked for the former, gradually passed into lodes of sulphuret of copper and iron, though these formed a very small part of the veins at the surface. Rich specimens of the double sulphurets from the Harlan mine, Guilford county, were exhibited, in which mine the lode is over ten feet thick, for the depth of one hundred and five feet, and consists almost entirely of these ores.

Some account of King's silver mine, Davidson county, was given, and specimens of the varieties of the silver ore shown. The mine was originally worked for lead, the ore being a carbonate, very rich, and in beautiful crystals. Native silver was discovered, and the pig lead already made, found to contain a considerable amount of that metal. Phosphate of lead, copper, zinc and sulphuret of iron, were also mentioned as occurring in the lode, which was twelve feet thick. Some of the ore was of a soft, light magnesian character, and though its specific gravity could not be twice that of water, yet it was considered a rich silver ore.

The lode lies between granite and a magnesian rock above. All the metalliferous veins, it is believed, are found at the point of contact of these two rocks.

Peter A. Browne, Esq. presented to the Association a section of the rock strata on the Schuylkill, above Philadelphia, drawn about the year 1825, being the first geological section made in the state of Pennsylvania.

Dr. Houghton then made some remarks upon the subject of the metalliferous veins of the northern peninsula of Michigan.

He began by remarking, that that portion of Michigan lying between Lakes Huron and Michigan on the south, and Lake Superior on the north, is known as the upper or northern peninsula, while that portion of the state lying south of the Straits of Mackinac, is more usually known as the southern or lower peninsula.

The rocks of the easterly portion of the upper peninsula, for a distance of one hundred and fifty miles, consist of a series of fossilferous limestones and shales, resting upon sandstones, the whole dipping a few degrees east of south. The limestones appear only on the southerly portion of the peninsula, while the underlying sand-rocks form the immediate coast of Lake Superior.

At a point very nearly one hundred and fifty miles west from the easterly extremity of the peninsula, and near to the immediate coast of Lake Superior, several low ranges of granitic hills make their appearance, which hills are flanked on the south, by quartz rock, alternating with mica, talcose, and clay slates. These hills have a general easterly and westerly direction.

Northerly from these, other ranges of hills occur, having a similar direction, but in the several ranges as we proceed north, the granitic character becomes less and less perfectly defined, being first sienitic, after this, altered sienite, and finally the outer or northern range is made up of well defined trap. This range of trap hills continues very nearly unbroken for a distance of one hundred and thirty-five miles within the limits of Michigan.

The trap rock, which chiefly appears as a compact greenstone, is nevertheless, quite uniformly bounded on the north by an amygdaloid, against or upon which rests a very coarse conglomerate, and upon this a series of alternating strata of conglomerate and sandstone, the whole being capped by an extensive formation of red sandstone.

The group of stratified rocks referred to, which have an entire thickness of several thousand feet, dip very regularly, and usually at a high angle, into the basin of Lake Superior; and since the same is the fact in regard to the rocks upon the north coast, that lake may be said to occupy a synclinal basin.

After some remarks upon the successive elevation of the several ranges of hills referred to, together with the long intervals of time that would appear to have elapsed between the several uplifts, Dr. H. proceeded to say, that with our present imperfect maps, it would be nearly impossible to convey a clear conception of its geographical geology, and that in fact he had made these references, only to render more intelligible what he wished to say upon the subject of the metalliferous veins of the district.

It is a fact well known, that south from the district referred to, transported masses of native copper are occasionally met with, in the diluvial deposits which are so abundantly spread over the country; and these loose masses are distributed over an area of many thousand miles, including southern Michigan, Wisconsin, Illinois and Indiana. In northern Michigan they are still more frequently met with.

The great transported mass of native copper on the Ontonagan river, so frequently alluded to by travellers, and which he, Dr. H., estimated to contain about four tons of native metal, was stated to have all the characters of the other loose masses referred to.

The source of these transported masses has, heretofore, been somewhat obscure, although there has been good reason to believe, that most of them had their origin from the trap rocks, but whether from true veins or from the mass of the rock itself, was not known. He said that after examining the country with care, he was enabled to state, that without doubt a very considerable portion of them had their origin from what may be regarded as true veins.

Those which were regarded as true veins, were uniformly noticed to originate in the trap rock, but they were frequently traced across the superimposed sedimentary rocks, to and including the red sandstone. The direction of the veins across the upper rocks most frequently corresponds to the dip of those rocks.

Dykes of trap, traversing the conglomerate and sandstone, were stated to be of frequent occurrence; but these dykes very rarely cut *across* the strata of the upper rocks, or in other words, they mostly occupy places corresponding to the lines of stratification, for which reason the veins referred to cut across the dykes at very high angles.

So far as we are enabled to judge from the examinations which have been made, those veins originating in the outer range of trap hills are the only ones in the district deserving the name of metalliferous veins. Not only do the separate veins vary from a mere line to several feet in thickness, but those traversing the several rocks above the trap, are usually very much expanded in their passage across the upper rocks.

By far the most important minerals contained in these veins are the several ores of copper. The metal occurs in a native form associated with the gray and red oxides, carbonate and silicate, together with several mixed compounds. Sulphuret of copper is exceedingly rare, and pyritous copper has not been found in what was regarded as a true vein, though this last named mineral, associated with the sulphuret and carbonate of lead, was noticed in small ramifying veins, in what may perhaps be regarded as a distant portion of the range under consideration. Native silver was very rarely seen in the form of specks and strings associated with the native copper.

Most of the ores of copper occur in the greenstone, amygdaloid and lower portions of the conglomerate, or at points in near proximity to the dykes before referred to, and they are most abundant at, or near to the junction of the trap and conglomerate, or in immediate vicinity of the dykes, thus following the general laws respecting the deposits of the metallic minerals.

As the veins recede from the trap, the place of the copper is frequently supplied by the silicious oxide and carbonate of zinc, together with calcareous spar, which latter usually fills the entire vein in its passage across the sandstone.

The veinstone in those portions of the vein most rich in the ores of copper is chiefly quartz, and this is frequently filled with minute specks and filaments of the native metal.

Dr. H. conceives these to be veins of sublimation, or in other words, to be simple fissures filled from below by the metal in a vaporous state, and that all the compounds had their origin from copper in a native form. The conglomerate was stated to have been noticed where the cement consisted to a large extent of ores of copper, and even of copper in a native state. This was observed only in close proximity to considerable veins.

The veins, as well as different portions of the same vein, are very variable in their metalliferous character, portions being apparently rich, while others are completely barren. With the present knowledge upon the subject, we can scarcely arrive at safe conclusions as to the value of these veins for the purposes of mining, but upon the whole they may be looked upon favorably rather than otherwise.

Adjourned to 4 o'clock this afternoon.

Friday, 4 o'clock, P. M. — Prof. SILLIMAN being absent, Dr. LOCKE was called to the chair.

Dr. JACKSON gave his views in relation to the construction of geological maps, suggesting the importance of concert and uniformity in design and execution, as regards *scale*, *coloring*, *symbols*, &c. on the part of the various state geologists employed throughout the Union. The subject was further discussed by Dr. Locke and Prof. Johnson, who concurred in the views of Dr. Jackson.

On motion of Prof. MATHER, the subject was referred to a committee consisting of Dr. JACKSON, Dr. LOCKE, and Prof. MATHER, who are to report at the next annual session of the Association.

Prof. JOHNSON exhibited a section drawn across the Frostburg coal basin, extending between the Little Alleghany and Savage Mountains, a distance of about four miles. He offered some observations concerning this coal-field, and enlarged upon its value and importance as a coal and iron region.

Mr. HODGE and Mr. TREGO, who had explored that portion of this basin which extends into Pennsylvania, also made some remarks in which they differed from the views of Prof. Johnson; particularly with regard to his opinion that some of the upper strata of the carboniferous rocks near the Savage Mountain, rest *unconformably* upon the lower ones.

Mr. HODGE placed on the table some clay concretions from Kennebec river.

On motion of Dr. BECK, *Resolved*, That when this Association terminates its present session, it adjourn to meet in Boston, on the last Monday in April next.

Dr. Jackson, Prof. Hitchcock, and Mr. Moses B. Williams, were appointed a local committee, (pursuant to a resolution reported by the committee on business,) for the purpose of making suitable arrangements for the next session of the Association.

The Secretaries were intrusted with the preparation and publication of an abstract of the proceedings of the Association.

Resolved, That the chairman of the present session be requested to open the next session by an address.

Dr. S. G. Morton was then appointed Chairman, and Dr. Jackson Secretary, for the next session.

Dr. L. C. Beck, Prof. H. D. Rogers, Prof. Hitchcock, Dr. Locke, and Dr. Jackson, were appointed a committee to prepare a constitution, by-laws, &c. for the government of the Association, according to a resolution of the committee on business.

Dr. Griscom made a communication respecting the Duane "steel ore" of New York.

Adjourned to 9 o'clock to-morrow morning.

At 8 o'clock in the evening the Association had the pleasure, in common with a respectable audience of ladies and gentlemen of Philadelphia, of hearing a most interesting and instructive address from Prof. Silliman, on the general principles of geology, and subjects connected with its progress in America.

Fifth day of Session, Saturday, April 10, 1841.—The Association met this morning according to adjournment of yesterday. Dr. Locke in the chair.

The minutes of yesterday's proceedings were read and adopted.

Dr. Morton opened before the Association a vessel of earthen ware taken from the Pyramids of Sakhara in Egypt, and forwarded to him by the American consul at Cairo, which contained an embalmed body of the *Ibis religiosa*, or sacred bird of the ancient Egyptians. The earthen vessel containing this relic of the most remote antiquity, was of a cylindrical or rather a conical shape, having a lid or cover fixed on the larger end, closely fitted on and luted with a composition resembling common mortar of lime and sand.

Dr. M. remarked upon the interest attending these relics, owing to their complete preservation — the bones, feathers, and even animal matter being frequently found almost unchanged, except by desiccation. The specimen opened was one of uncommon interest on account of the great perfection and almost interminable number of the bandages of linen cloth in which it was enfolded, and the high preservation of the most delicate parts of the plumage. The position of the bird in the embalmed specimens is found to be invariably the same. The neck and head are drawn down between the legs, the lower mandible being presented outward and downward, and the legs drawn forward beneath the body of the bird, as if in a sitting posture, with the wings folded over the neck and legs. Some specimens less perfectly bandaged seem to have undergone a process of carbonization, and on the removal of the linen folds crumble into a dark powder, in which the bones appear, though reduced to a brittle state.

Dr. Morton referred to the very recent appearance of the pottery ware in which these specimens were contained; notwithstanding their extremely ancient date, which is at least three thousand to four thousand years. The pyramids of Sakhara are among the most ancient monuments of human art. These cases containing the embalmed ibis are still found in great numbers, though the traveller, Dr. Pococke, gave his opinion one hundred years ago, that they would probably soon become extinct.

Dr. Morton then proceeded to open another envelope containing some unknown embalmed object, which he conjectured to be a mass of snakes or serpents. This was less carefully enclosed than the ibis, being coarsely enveloped in rags rather than bandages, though still covered by hundreds of folds of linen. These being at length removed, disclosed *the wing of a bat!*

The next embalmed object unfolded was a young crocodile, (*Crocodilus Niloticus*,) about a foot in length, and in good preservation. Dr. M. observed that this animal is found in embalmed specimens of all sizes, from the apparently just hatched young to those of five feet in length, one of the latter size being at present in his collection.

Mr. Quinby exhibited specimens of silver, lead, and other ores from the Andes in Peru, accompanying them with some observations upon their product, situation, &c.

Prof. Johnson showed specimens of magnetic iron ore from the State of New York, which he had found to contain titanic acid, combined with iron and manganese.

Dr. Locke made some observations on the application of magnetism to the discovery of metallic veins and deposits.

The following resolutions being moved by Prof. Rogers, were unanimously adopted.

Resolved, 1. That the thanks of the Association be presented to Prof. SILLIMAN, for the interesting lecture delivered by him last evening.

2. That the thanks of the Association be presented to the Academy of Natural Sciences for the use of their rooms during the present session.

3. That the sincere thanks of the Association be presented to Prof. SILLIMAN, for the highly able manner in which he has discharged the duties of chairman at the present annual meeting.

4. That the thanks of the Association be presented to Dr. BECK for the able and laborious manner in which he has discharged the duties of secretary throughout the first year, and at the present meeting. Also that the thanks of the Association be given to Messrs. B. SILLIMAN, JR., and CHARLES B. TREGO, for their valuable services as assistant secretaries.

On motion of Prof. ROGERS, amended by B. SILLIMAN, JR., it was *Resolved*, That the Association publish five hundred copies of the address of Prof. Hitchcock, under the direction of the secretaries, which shall be distributed, as soon as practicable, to all the members of the Association; and that the expense of publication be defrayed by a pro rata charge on each member, to be paid at the next meeting of the Association in Boston. Such copies as are not distributed to members under this resolution, to be sold for the benefit of the Association.

On motion of Prof. J. C. BOOTH, it was also *Resolved*, That the names of all the officers of the Association, of the local committee, and the names and addresses of all the members of the Association, be appended to the address of Prof. Hitchcock.

The Association then adjourned to meet in Boston on the last Monday in April next, (1842.)

B. SILLIMAN, *Chairman*.

L. C. BECK, *Secretary*.
B. SILLIMAN, JR.
CHARLES B. TREGO, } *Assistant Secretaries*.

THIRD SESSION. 1842.

Monday, April 25th, 1842, 9 o'clock, A. M. — Association met at Boston, pursuant to adjournment of last meeting.

Dr. MORTON (the chairman) not having arrived, Prof. LOCKE was called to the chair. Dr. C. T. JACKSON, was chosen secretary. Mr. JOSIAH D. WHITNEY and Mr. MOSES B. WILLIAMS were appointed assistant secretaries.

Letters were then read by the secretary from Messrs. W. W. MATHER, ROBERT GILMORE, H. H. HAYDEN, BARON LEDERER, FRANCIS MARKOE, JR., R. HARLAN, and Dr. DOUGLASS HOUGHTON, regretting their inability to attend the meeting. It was then,

Resolved, That all those gentlemen, whether of this or any other country, who are interested in geology and the allied branches of science, and who may be present on this occasion, be invited to unite with the Association in its deliberations.

A letter being read by the secretary from Prof. SILLIMAN, stating his readiness to comply with the wishes of the Association, either to deliver his address before the Association alone or before the public: — It was

Resolved, That the address of Prof. Silliman be delivered to the Association in presence of the public.

Resolved, That the local committee be authorized to make all necessary arrangements for the accommodation of the audience during the delivery of this address.

Resolved, That any gentleman requesting permission to read a paper, on condition that it be returned to him without an abstract of its contents having been entered on the minutes, may have the privilege, on merely allowing its title to be recorded. Provided only, that in all cases where the paper is to be withdrawn, as above, there shall be no discussion on the subject.

The Association then adjourned until 3½ o'clock, P. M.

NOTE. As a rule of the Association excludes oral remarks from the records, on account of the difficulty of reporting them correctly, but sanctions the subsequent communication of them by their authors, and as these minutes were thus furnished by some gentlemen and not by others, this will account for the very disproportionate space occupied by the remarks of different individuals, as published in the annexed abstract of the proceedings. Many valuable observations have thus been lost which there is much occasion to regret, and particularly those of Mr. Lyell, of which no minutes were communicated, although the Association listened to him with much satisfaction during the several periods when he favored them with his views.

Monday, April 25th, 3½ o'clock, P. M., Prof. LOCKE in the chair.

Prof. LOCKE exhibited sections of the rocks of the lead regions of the Upper Mississippi, with remarks on the geology of the West.

Prof. L. proceeded to state as follows: — I present to-day some geological sections of the lead region of the Upper Mississippi. These were made by myself during the survey of the Mineral Lands, ordered by Congress, and by Dr. Owen and myself with numerous assistants in 1839. A detailed report of that survey was made to the Department of the Land Office early in 1840, but owing to some mismanagement at Washington, it was published without the illustrations, which were numerous, and so connected with the text that the document became nearly unintelligible without them. As this paper, imperfect as it is, has been seen by few of our geologists, and as the sections before us are chiefly in connection with what I have denominated the cliff limestone of the West, I will ask leave to read from my printed report some remarks upon that rock. This I do more especially, as it appears not to be known or recollected that I have a claim to the discovery that the metalliferous rock of the Mississippi is identical with the cliff limestone of Ohio, and that the same rock, wherever it has been found, is more or less metalliferous. [Here was read part of the Report of Prof. L. to Dr. Owen, referred to as published in Document 239, 26th Congress, United States. — The following sections were also exhibited and explained.]

" I. A section from the heights of Little Mahoqueta through Dubuque Mines to Sinsinawa Mound, fifteen miles. This section exhibited,

1. The cliff limestone, containing in its middle and lower portions the lead veins.
2. The blue limestone, (Trenton limestone.)
3. Presumptively, the lower magnesian underlying the blue.

" II. A section at Prairie du Chien, exhibiting the following rocks, descending series:

1. Soil and cliff limestone,	60 feet.
2. Blue fossiliferous limestone,	115 "
3. Buff colored limestone,	20 "
4. Soft saccharoid sandstone,	40 "
5. A portion covered by soil,	40 "
6. Lower magnesian limestone resembling the cliff, lithologically, but nearly destitute of fossils,	190 "
7. Saccharoid sandstone,	30 "
This last is exposed only at low water.	——
Total,	495 feet.

" III. A section from Blue Mounds to Wiskonsin River, exhibiting the following descending series of rocks:

1. Beds of siliceous chert, containing the fossils of the cliff and forming the peaks of the mounds, .	410	feet.
2. The cliff limestone, containing in its lower portion lead ore, ...	169	"
3. The blue fossiliferous limestone, very thin, and in some places wanting, ...	00	"
4. Saccharoid sandstone, ...	40	"
5. Alternations of saccharoid sandstone and lower magnesian limestone, ...	188	"
6. Sandstone, ...	3	"
7. Lower magnesian limestone, ...	190	"
Total, ...	1000	feet.

By lower magnesian limestone is not meant the magnesian limestone of Europe. The name was given by Dr. Owen in contradistinction to the cliff limestone, (which is the upper magnesian,) both containing magnesia. What has been denominated by me the cliff limestone,—a name adopted by Dr. Owen,—is properly divided into three portions, which other geologists may consider three distinct formations.

The following is Dr. Owen's subdivision of the cliff series: p. 24, Document 239, 26th Congress.

" *Upper beds.*— More regularly stratified, and less frequently vertically fissured than the middle and lower. Also, more rich in siliceous fossils, containing layers of chert, and indeed passing wholly into masses of flinty rocks, containing also good iron ore, and much crystallized carbonate of lime; but lead rarely, and in unprofitable quantities.

" *Middle beds.*— Aspect more arenaceous, though it contains but a small per centage of sand. Cherty masses are rare. Stratification imperfect, with numerous vertical fissures. Rich in ores of lead and zinc, associated with iron in small quantities.

" *Lower beds* — Also of arenaceous appearance; rather more distinctly stratified than the middle beds, and imbedding more frequently than these siliceous cherty masses. They contain the same ores as the middle beds, with the addition of copper ore and sulphuret of zinc."

These several beds are distinguished by their fossils. The several fossils enumerated by Dr. Owen are:

"*Upper beds.*— *Terebratulæ*, several species of *Catenipora, Calamipora, Columnaria tubipora, Aulopora, Sarcissula, Astrea, Cyathophylla, Caryophylla* and *Orthoceratites.*

" *Middle and lower beds.*— *Coscinipora,* (*sulcata? Gr.*) the only coralline, a *Cirrus* resembling *perspectivus; Ampullaria,* imperfect impressions of a long spiral univalve, resembling the genus *Vivipara.* It seems by the above, that there was no absolute zoological distinction between the middle and lower beds."

Permit me here to add as a claim of the western geologists, rather strangely overlooked by some *eastern* writers on *western* geology,—that besides these, all the other western rocks yet made known, have been described by western geologists. Especially the bed of mountain or carboniferous limestone, superimposed on the cliff at the upper rapids of Mississippi, underlying the great Illinois coal basin, cropping out at St. Louis, and forming the bluffs at and above Alton, Illinois, with its characteristic fossil, the *Archimedes* of LeSueur, was well known to Messrs. Troost, Owen and myself. The same rock occurs within the limits of the survey of the Professors Rogers, who belong, in part at least, to the western corps. In 1839, I had the pleasure of comparing notes with Prof. James Rogers, on the characters of this very rock as it occurs in Indiana and Illinois on the one part, and in Western Virginia on the other. I hope yet more specifically to settle the claims of the various *laborers* in our western geology. At the same time I would observe, that it is impossible for an eastern geologist, without visiting the West, or even by a post-haste journey over the trans-Appalachian world, to write upon its geology without committing errors injurious to his own reputation, the publication of which he would, of course, gladly recall.

Remarks were offered and facts stated, on the above subject, by Dr. King, Mr. Haldeman, Mr. Teschemacher, Prof. Henry D. Rogers, Dr. C. T. Jackson, Prof. Vanuxem, Prof. Hitchcock, Prof. Beck and Dr. Dana.

Mr. Haldeman laid on the table, at the request of Dr. Morton, some copies of a work on cretaceous fossils, bringing our knowledge of this subject near the present day, most of these being from the researches of Prof. Nicollet.

A letter was read from Prof. Park, of Philadelphia, regretting his inability to attend the present meeting. The Association adjourned to,

Tuesday, April 26th, 9 o'clock A. M.—Prof. Locke in the chair. The committee on the constitution and by-laws was called upon for a report. Dr. Jackson read the rules, as submitted by this committee.

Dr. Morton having arrived, took the chair as president of the meeting.

Resolved, That Prof. Locke, Dr. Jackson, and Prof. Hitchcock, be appointed a committee to prepare business for the Association.

Prof. Hitchcock then read a paper "on the Phenomena of Drift in this country," which was illustrated by numerous drawings, and a map of the United States, on which were drawn lines representing the course of the striæ, and lines of dispersion of bowlders. In the course of his paper, Prof. H. called on Mr.

Gray to describe a remarkable moraine in Andover, Mass. Mr. Gray stated this moraine to be one mile long and fifteen or twenty feet in height. At the close of this paper, an animated and extended discussion arose on the subject of drift.

Dr. Jackson objected to the views of Prof. Hitchcock, as published in a recent report on the Geology of Massachusetts, but having had an opportunity, since those views were published, of conversing freely with Prof. H., he found but little real difference in their present opinions. He would, however, by no means consider that we could yet form an unobjectionable theory on the subject of drift, polished grooves, and the transportation of erratic blocks of stone. If we admit several different causes, how remarkable would it be, should they be found to have acted in nearly the same direction! Yet we cannot agree upon any known cause, as sufficient to explain all the facts. This country exhibits no proofs of the glacial theory as taught by Agassiz, but on the contrary the general bearing of the facts is against that theory; for we observe nowhere in this country a general radiation of detritus from the principal mountain ranges, although, as in Rhode Island, there is a divergence from the point whence the bowlders were derived. This divergence is, however, merely a spreading of fifteen miles for forty in extent, and it is in the usual general direction of North American drift to the southward, none of the bowlders having been drifted to the north of their parent bed.

Mr. Lyell offered some remarks on the subject of the distribution of bowlders and of the furrows in the rocks, citing the result of many observations in Europe.

Mr. Redfield had, from his limited observations, been led to infer that the drift of the region near New York was the joint result of glacial and aqueous action, and was mainly deposited during a period of increasing submergence. Mr. Redfield also alluded to the agreement of the striæ of the polished rocks, and of the transported bowlders and drift, with the known course of the existing polar currents of the ocean, in the northern hemisphere, and suggested that this system of currents, being essentially the same in both hemispheres, and having its cause in the dynamics of the solar system, must have operated through all time, and over extensive regions, but varying in locality and direction with the changes of outline and relative levels of seas and continents, during successive geological periods.

Some discussion then ensued on the question whether the mounds of the western United States were the result of natural diluvial causes, or the work of the Indians.

Mr. LYELL cited an instance where the inhabitants of Scandinavia, had taken advantage of a long and very high natural ridge, to form three separate mounds, which were afterwards considered as the burial places of their fabulous deities.

Prof. SILLIMAN remarked with respect to the genuineness of mounds, as works of man, in contradistinction from those natural piles that have been cut out of the strata of clay, sand, gravel, loam, &c., and rounded and shaped by water so as to resemble works of art — that artificial mounds (found in many and distant countries, both on the eastern and western continent,) appear to have been characteristic of a particular state of society, advanced beyond barbarism, but not yet sufficiently civilized for the construction of massy sepulchres of solid stone, sarcophagi, pyramids and temples. He appealed to those numerous mounds which form the most impressive feature of the scenery on Salisbury plain in Wiltshire, in the southwest of England. Prof. S. had counted seventy of these mounds in one view, while sitting upon his horse upon the top of a low one; and from the same place Dr. Stukeley says that he enumerated one hundred and twenty-eight. These mounds are rarely less than thirty feet in diameter; they are generally surrounded by a broad ditch, enclosed by a circular or oblong parapet or embankment. Near Overton in the west of England, Prof. S. ascended one which was one hundred and seventy feet high and whose base covered about an acre of ground, its form being that of the lower segment of a cone.

The void, from which the earth was taken, remains to this day, and is as evidently an artificial excavation to form an artificial hill, as any modern fortification with its ditch and glacis. There remains not the smallest doubt, that these mounds were erected both as sepulchres for distinguished individuals, and as monuments of victories. The remains of the dead have been often found in them, either skeletons or ashes — with heads of spears, swords, bones of horses, dogs and other domestic animals; sometimes beads, trinkets, and female ornaments; articles dear to the departed while living, and which were believed to be important to them in another world.

Prof. H. D. ROGERS remarked, in relation to Mr. Lyell's opinion of the gradual rising of the North American terraces, that if such were the case, fossil shells or marine sedimentary accumulations should be found at all elevations uninterruptedly, on the mountain slopes which are covered with marks of diluvial action. It has not been shown by examination that such is the case;

hence he infers that the cause which produced the elevation was paroxysmal in its operation and effects, and not secular, or gradual and uninterrupted. In order to explain the theory of diluvial phenomena, he would suppose with Mr. Lyell and others, that the region around the north pole was capped with ice, in immense masses, and that, by a sudden outburst of volcanic action, this was dispersed, and sent in a quaquaversal direction towards the equator. But if we suppose that this was accompanied by an earthquake, rocking, or wave-like motion of the bed of the ocean, the whole mass of torn-up strata would be shoved violently from north to south, and at every heaving of the earth, a mass of water would be thrown forward, like the rolling in of a tremendous surf. Mr. Couthouy's observations among the coral islands, would go to strengthen this theory, while the rocking movement of the earth's surface during an earthquake, had been long ago admitted.

Mr. Couthouy remarked, in relation to the paroxysmal rise of the land at intervals, that on one island which he had visited, which was about two hundred feet in elevation, about one half-way from the base to the summit, the face of the cliff was deeply sea-worn and indented; and were it at this moment to be still further elevated above the ocean level, it would present similar marks of powerful and long-continued action of water, at the part which was before on a line with the sea. In regard to the bowl-shaped cavities, encircled on all sides by regular hills, he suggested that they might have been worn by the rotary motion of icebergs; this rotary or semi-rotary motion of the icebergs, he had noticed both in those which were and were not stranded. They become gradually worn away on one side by the action of the water, when they turn over, with a displacement of the sea, and violent upheaving of the mud and sand, rendering the water turbid to a great distance.

The discussion was continued by Mr. Lyell and Mr. Couthouy, on the probable agency of icebergs in diluvial phenomena, and especially in regard to the water-worn cavities or pot-holes.

Dr. C. T. Jackson described the pot-holes which occur in Orange, near Canaan, in the elevated land between the Connecticut and Merrimack rivers in New Hampshire. They are worn in a hard granite-gneiss, in a line following the general north and south direction of the diluvial or drift current. One which had been cleared of the round, smooth stones which formerly filled it, and which is known to the inhabitants as "the well," is eleven feet deep, four and a quarter feet wide at the top, and two feet at the bottom. These pot-holes could not be referred to the action of any existing current of water, as they are on the water-shed line, between the two rivers, and more than one thousand feet above the sea level.

Mr. John H. Blake was requested to prepare a paper on the tertiary and drift of the Andes.

Prof. H. D. Rogers remarked, in relation to stranded icebergs, that coming from the north, loaded with bowlders, and stranded far above the sea level, they would, while melting, produce all the phenomena of the glaciers of the Alps.

Mr. Couthouy was requested to draw up a paper, embracing the facts which he had collected in regard to icebergs, and lay it before the Association. Mr. C. having, in accordance with this request, prepared the following summary of his observations and the remarks he had made concerning them, at the present session, it is here inserted.

Mr. C. premised that in order to give the remarks he was about to submit, their full weight, it might be proper for him to state, that he had no preconceived opinion — no hypothesis of his own upon this question, to sustain. His intention was simply to offer a few facts which had fallen under his personal observation, with the inferences to which they had led his own mind, leaving abler judges to decide upon the value of such facts and the correctness of the inferences. He remarked that the opportunity of witnessing the actual operation of the huge bodies of drifting ice, known as bergs or islands, was of so rare occurrence that its true character appeared to him not clearly understood, and consequently, geologists were liable to overlook or err in judgment upon some important points in the dynamics of aqueo-glacial agency. Mr. C. then proceeded to a statement of the geographical position of a number of icebergs, as determined by reference to his journals. The first noted was observed on the 28th of May, 1822, during a passage from Havanna to Rotterdam, and was in 42° 10′ N. lat., 44° 50′ W. from Greenwich. Its size must have been very considerable, as it was visible from the deck of a vessel of two hundred tons, for eighteen miles. Numerous small streams of water were pouring down its sides, and a boat was sent with a view to obtain a supply, but on approaching it, the swell, notwithstanding its being quite calm, was found to dash against its face with such force, and the lower portions were so worn and ragged, as to render it inaccessible. Although the weather was so serene, and the sea so tranquil, yet the berg was constantly turning slowly round as the swell struck its many promontoriform projections. It appeared to have lost little of its primal magnitude, the summits retaining a conical or rounded form, instead of being worn, like others he had seen, into sharp pinnacles and acicular ridges, by the action of the atmosphere and rain.

The next observed by Mr. C., was on the return passage, in September of the same year. It was aground on the eastern edge of the great Bank of Newfoundland, in 43° 48′ N. lat., 48° 30′ W. long. Sounding three miles inside of it, the depth was found to be one hundred and five fathoms, and as the water deepens rapidly toward the edge of the bank, the berg must have been in at least one hundred and twenty or one hundred and thirty fathoms. There was a heavy sea running at the time, causing it to rock and oscillate horizontally, to and fro, with a heavy grinding noise, distinctly audible to all on board. A fresh wind from the east was continually forcing it further up on the bank, but in the event of a contrary gale springing up, it would doubtless have been driven off again into deep water, to pursue its course to a milder clime, loaded with materials ground into its base while stranded.

Between this period and the summer of 1827, several icebergs were seen by Mr. C., but not being able at present to lay hand on his journals of that interval, he could enter into no particulars, further than to state that as, with a few exceptions, his voyages were between the United States or West Indies and Great Britain or the Mediterranean, it was probable that they were chiefly met between the 36th and 42d parallels of north latitude. He remembered however, having encountered in November, 1825, off the entrance to the Rio de la Plata, in latitude 35° south, longitude 49° west, or thereabouts, a number of icebergs, some of which were of large magnitude; a reference to the chart would, he observed, show to what a vast distance from their birth-place these floating masses had been driven by wind and current.

In the month of August, 1827, while crossing the Grand Banks, in latitude 46° 30′ north, longitude 48° west, Mr. C. passed within less than a mile of a large berg which was stranded in between eighty and ninety fathoms water. The wind was light, but a heavy swell was running from the westward, and the huge pile could be distinctly seen to rock and shake violently as it ground heavily down into its bed with every surge. Owing to its longest diameter facing the swell, the mass had an oscillatory or semi-rotary back and forward motion upon its vertical axis, according as the sea broke upon one or the other extremity, which it did with so much force at times as to turn the berg apparently fully half round: in this situation it would remain till another heavy surge striking the opposite end would force it back and round in the other direction. The vessel was sufficiently near for Mr. C. to perceive distinctly, large fragments of rock and quantities of earthy matter imbedded in the sides of the iceberg, and to see from the fore yard, that the water for at least a quarter of a mile round it, was full of mud, stirred up from the bottom by the violent rolling and crushing of the mass. This movement was accompanied by a harsh grating noise, with occasional cracking reports, resembling those produced by blasting rocks, which might have been heard ten or twelve miles. The height of this berg was estimated by Mr. C., at from fifty to seventy feet, and its length at four hundred yards. While examining it through the glass, it was observed to incline suddenly more than usual, and in the next moment, with a crash and roar that were truly fearful, and amid a whirlwind of spray and foam, the whole enormous pile rolled over on its side, tearing up with it, no doubt, large quantities of matter from the bottom, and loading the sea with mud and sand for more than a mile in all directions from its bed.

April 27, 1829, Mr. C. passed, in lat. 36° 10′ N. lon. 39° W. near the middle of the Gulf Stream, which there set in an east-south-easterly direction, an iceberg, estimated to be a quarter of a mile long, and from eighty to one hundred feet high. It was much wasted in its upper portion, which was worn and broken into the most fanciful shapes, forming resemblances of minarets, spires, pyramids and castellated ridges, whose character was momentarily changing by reason of the berg moving backward and forward horizontally with great quickness. A strong breeze, and numerous smaller fragments of ice floating in its vicinity, prevented a very near approach, but on one side, a large earthy colored patch was seen, having numerous blacker spots, which Mr. C. had no doubt were bowlders, scattered over it. Some of these presented a surface of two or three hundred square feet.

In 1831, on a passage from Boston to Mobile, at daylight of 17th August, in latitude 36° 20′ north, longitude 67° 45′ west, upon the southern edge of the Gulf Stream, Mr. C. fell in with several small bergs in such proximity to each other, as to leave little doubt of their being fragments of a large one, which, weakened by the high temperature of the surrounding water, had fallen asunder during a strong gale which for several days previous had prevailed from the southeast. The natural tendency of this would be to force the berg into the warm northeast current of the stream, where, already much worn by its prior sojourn there while crossing from the north, its separation soon took place. The strong northwest wind immediately following the southeast gale, probably drove the fragments out of the Gulf again, to where they were seen in the eddy current, which Mr. C. found to set in that place southwest, at the rate of half a mile per hour. And here, said he, a suggestion of much geological interest presented itself to his mind. Supposing an iceberg of the present day to break loose from the northern polar regions, loaded with blocks of stone and gravel, and drifting southward, to strand upon the Banks of Newfoundland, or George's bank near our own shores, and there remain for a considerable period grinding itself upon the ocean's bed, thereby incorporating into its mass, portions of it, such as shells, gravel, sand, clay or stones. Owing to the unequal action of the weather upon its surface, and of water on its submerged portion, it might, as has been shown, turn partially or even entirely over, thus placing the newly gathered matter above water; and if the old were at the bottom previously to the overturn, mixing together the rocks from both localities. Loaded with this additional material, it might float off and resume its southerly course, be accidentally forced into the Gulf Stream and carried eastward at the rate of 24′ a day, (the mean velocity of the Stream in the meridian referred to,) till it was melted away. To effect this dissolution would require three or four months, during which time, the berg would be carried six or seven hundred miles in a direction nearly at right angles with its primary drift, depositing a greater or less quantity of transported material along its entire track. Mr. Couthouy remarked that the instance just cited, was one of peculiar interest, from its illustrating the manner in which rocky materials imbedded in icebergs, may, through the devious course of these latter, be deposited along a wide range of longitude as well as latitude. He called attention to the fact that this berg was to the southward of the Gulf Stream, and about 18° or seven hundred and fifty miles west of a meridional line, passing through the centre of the grand Bank of Newfoundland. It was the only case within his knowledge, of an iceberg being seen so near our continent in this parallel. He showed, by reference to a chart of the Atlantic, that in all probability this one entered the Gulf Stream at least as far eastward as the 48th deg. of west longitude, and in the 42d or 43d parallel of north latitude. It was his opinion that this occurred in the spring of the year, when the prevalent strong northeast winds would drive it southerly across the stream with nearly as much rapidity as the latter would carry it forward in an easterly direction. To exemplify this, said Mr. C., we should work out the drift and true course of this berg, precisely as a seaman would do that of a ship hove to the wind for the same length of time, and under like circumstances. Assuming then, that the berg in question had impinged upon the Gulf Stream in the latitude and longitude above given, and there encountered one of the northeast gales, so frequent, and of such long continuance on our coast in the spring, half a mile per hour would be a moderate allowance for its set southwestward by the wind and heave of the sea. In forty days, (and it is well known that easterly gales often prevail over this part of the Atlantic during the spring months, for even a longer period,) in forty days, it would, were there no opposing agency at work, be propelled three hundred and forty miles west, and the same distance south of its point of entrance into the Gulf Stream. But as, in this parallel, there is a current setting in an east by south direction, with a mean velocity of three quarters of a mile per hour, this would, during the assumed period, not only counteract the wasting caused by the swell, but carry the berg three hundred and sixty-eight miles east, and one hundred and twenty miles further south, making its true line of drift up to the close of the forty days, to be south 38° east, and the distance traversed four hundred and seventy miles. This would place it in latitude 34° 50′ north, longitude 38° 30′ west, or about across the

Stream, here not far from four hundred and fifty miles wide. From this point to the locality in which the fragments were seen, its course would be about south 84° west, and the distance one thousand four hundred and seventy miles. Assuming that the eddy current and heave of the sea combined, were equal to impelling it westward at the rate of three quarters of a mile an hour, it would require about eighty days to transport it to the locality in question. But as the wind, although acting upon it generally from the eastward, cannot be supposed to have done so constantly, it might be a considerably longer time in performing the voyage.

Mr. Couthouy exhibited a chart of the Atlantic, with the assumed track of the iceberg met by him, marked upon it, and pointed out that its drift westward must have been at least as great as he had there represented; since it could not, owing to the trend of the coast of Newfoundland, have entered the Gulf to the westward of the point designated, but on the contrary was likely to have done so further eastward. Moreover, as it could by no possibility have reached the spot where he fell in with it, without having been driven across the Gulf Stream into the westerly eddy, it was obvious that unless the heave southwestward by the northeasterly wind and swell were admitted, it must have been for a much longer period in the Stream, and finally emerged to the southward of it, at a point much further south and east than he had assumed in his calculation of its course.

That a mass of ice so considerable should remain after so long a sojourn amid the warm waters of the Stream, would not, he observed, appear surprising, when the enormous magnitude of some of the masses that have been encountered by voyagers in these seas was taken into account; together with the fact that they produce by their dissolution, carry about with them, and occasion to a great distance around them, a very material decrease of temperature, both in the air and ocean, which tends to render the operation a much more gradual one than we might at the first glance imagine. From the record of a journal kept by Francis D. Mason, Esq., in June, 1810, on a passage from New York to Halifax, N. S., and published in Blunt's American Coast Pilot, edit. 1827, it appears that the water at seven miles from some icebergs, was from 12° to 15° below the average temperature where it was not affected by the presence of such bodies. One of these islands is represented as having been one hundred and fifty feet in height, and a mile in extent. It was easy to conceive of masses like this, resisting the action of air and water for a much longer period than would suffice to place the berg, whose course has just been described, so far from the point of its northern entrance into the Gulf Stream.

The last iceberg of which Mr. C. was prepared to speak from personal observation, was encountered by him on the 4th of March, 1841, in the Pacific ocean, during a passage from the Hawaiian islands to Boston. It was of great magnitude. Its height could not have been less than two hundred and eighty or three hundred feet, and its longest diameter two thirds of a mile. The ship, sailing at the rate of seven miles an hour, was two hours and three quarters in coming up with it after it was first seen from the deck, when it already loomed up like a large islet. Immediately on its discovery the ship was headed directly for it, till within half a mile of the berg, at which distance it was passed. Without the aid of a glass Mr. C. distinctly saw enormous masses of rock projecting from different parts of this ice mountain, some of them apparently having a surface of at least twenty feet square. The swell, which was very heavy from the westward, washed up the sloping sides to the height of eighty or one hundred feet, recoiling in vast sheets resembling cataracts; and where the face of the berg was perpendicular, the surf broke against it as if it had been a wall of rock, with tremendous force, and a booming roar like that of distant heavy thunder. There appeared to have been a recent overturn of the berg, inasmuch as the water for a mile's distance from it was full of fragments, some of them sufficiently large to endanger a vessel. One of the most remarkable phenomena observed by Mr. C., was the almost incredibly rapid revolution of this huge body on its vertical axis, in consequence of which it did not present the same aspect for two minutes together. One moment it was a pyramid, the next barn-shaped, and in another a glittering pile of peaks and serrated crests, or battlements, like those of some ancient castellated citadel, was exhibited. Scarcely was there time to sketch the rudest outline of one configuration, ere it gave place to another totally dissimilar. This melting away of the various figures, could be compared to nothing better than the sudden and fanciful changes we see in turning a kaleidoscope. Mr. Couthouy here exhibited to the Association a series of sketches taken at the time, as illustrative of the variety of form spoken of. The following statement of the temperature of the air and ocean at various distances from the berg, was given as evidence of the great extent to which they were affected by its presence, and the influence which, as before mentioned, this circumstance exerted on the retardation of the dissolution of similar masses:

	Noon.	2 P.M.	3 P.M.	3 30 P.M.	4 P.M.	4 30 P.M.	5 P.M.	5 30 P.M.
Air,	54°	53°	50°	46°	42°	37°	35°	37°
Water,	50°	50°	48°	44°	43°	36°	36°	40°
Distance of berg,	33′	19′ (visible,)	12′	8′	$4\frac{1}{4}$′	1′	3′	6′

When nearest the iceberg, (which was within a short half mile,) the water was at a little below 34° Fahr., and the air at 35°. After passing the island, when about two miles to leeward, a smart fall of hail was experienced, which lasted about ten minutes. By this statement it appears, that the water, three miles to leeward of the island, was 7° Fahr. colder than that four and a half miles to windward; and at six miles, 3° colder than at four and a half, and 4° colder than at eight miles to windward, owing probably to a surface current carrying the cold water from it in the direction the wind was blowing. The latitude of this ice island was 53° 20′ S., and its longitude

104° 50′ W., making its distance from Terra del Fuégo, the nearest eastern land, one thousand four hundred and fifty miles, and one thousand from St. Peter's and Alexander's Islands, the proximate southern land from which it could have been detached. From its great magnitude, it was the opinion of Mr. C. that should this berg have been driven by the westerly gales which prevail in that region of the Pacific during so large a portion of the year, into the current setting constantly to the northward along the whole west coast of South America, it might have floated to the verge of the tropics ere it dissolved entirely, or perhaps been stranded somewhere about the shores of the Chiloan Archipelago.

The attention of the Association was called to the fact of such large masses of rock, which were undoubtedly once at the bottom of the berg, being exposed on its face or sides. Mr. Couthouy conceived that the dissolution below the surface by the action of the water, and above it by that of the weather, being unequal in different portions of the berg, especially when it was aground, and consequently one side more constantly exposed to the sun's rays than the other; the equilibrium would be occasionally destroyed, the result of which would be an overturn, like that witnessed upon the Grand Banks, bringing to the surface portions of the mass containing rocks and earth. The U. S. ship Peacock, during her last cruise of discovery in the Antarctic Ocean, while attempting to penetrate the great barrier of ice, was seriously injured, and narrowly escaped utter destruction, from the separation and toppling down of a huge fragment of an iceberg. Had not this latter been still attached to the main body, there can be no question but that one of the violent overturns referred to, would have followed such a change in the proportions of the berg. Again, in the case of a drifting island, where from its rotary motion it is probable the waste from exposure would be nearly equal on all sides, it is evident that the side in which the rocks were imbedded, would, owing to their specific gravity being much greater than that of the ice, gradually preponderate, and either produce a sudden and violent change of axis, or slowly settle down once more, according as circumstances varied. In smooth, still water, the latter would probably occur, while the former might be expected to happen in a tempest or a heavy sea. In connection with these facts, Mr. C. submitted the following supposed case, as one by no means of improbable actual occurrence, the first portion of which, indeed, was merely a statement of what had really taken place in the great iceberg last described. Suppose an island of ice to be detached from the great southern barrier, having its base loaded with rocks, &c., and after drifting several hundred miles northward, to experience an overturn, bringing these rocks to the surface. It then floats on for a considerable distance further, till from the equilibrium being again destroyed, the rocky portion settles down and resumes its original position. These alternations may occur several times. Driven landward by the heavy westerly swell into the continental northern current, it is at length stranded on the coast of South America, and undergoes one or more overturns, bringing up at each time an additional amount of material. It then is forced off by a strong off-shore wind, and after drifting still further north is stranded again, perhaps at a long distance from its first anchorage. New overturns follow, fresh materials are accumulated, but from waste, the whole mass becoming lighter, it is once more floated off, and pursuing a somewhat devious course towards the tropics, is gradually melted away. Could that part of the ocean's bed over which such an iceberg has passed be laid bare for our inspection, what would be the appearances presented? The early progress of the mass would be marked by a deposition of large angular fragments of polar rocks. Subsequent to the overturn there would be an interval with few or no traces of its path, till the rocky portion of the berg had resumed its original situation, when the deposition would be continued, and these alternations would evidently correspond to the number of overturns. The larger masses of rock would for the most part be the first to drop out, and latterly the majority of matter might consist of smaller and more rounded fragments, such as had been worn by the grinding of the ice on the beach or bottom. Prior to the last, or even the first stranding, all, or nearly all the rock and earth originally contained in it might be deposited, when the latter portion of its track would be marked by a comparatively scanty amount of material from its more recent halting places, perhaps confusedly mixed, and affording here and there some slight indications of the birthplace of the berg, in the occasional presence of a fragment of the remote Antarctic soil.

Was there aught, asked Mr. C., in the evidences of ancient aqueo-glacial action, analogous to such a mixed deposition, and irregular distribution of materials from widely separated localities, as would result from the conjectural case here presented, or the actual one of the iceberg previously cited as fallen in with on the southern margin of the Gulf Stream? Did they explain any of the obstacles and apparent anomalies presented by the aqueo-glacial theory of the drift formation? These were questions which he submitted for the decision of those whose attention had been more specially directed to this subject.

In reference to the advance and northern limits of icebergs from the Antarctic in the eastern hemisphere, Mr. C. could state nothing from his personal knowledge, further than that they frequently occur at least as low as the thirty-fifth parallel of latitude. During his residence in New South Wales, in the summer and autumn of 1839–40, (December to March,) several ships arriving at Sydney from England, reported having fallen in with large icebergs in the vicinity of the Cape of Good Hope, at least eighteen hundred miles from the nearest southern land; along the whole of which distance they possibly deposited material from their polar starting point.

Mr. C. stated that he would here offer a few brief remarks upon the bearing of the facts he had submitted upon the question of the results of aqueo-glacial action in past times, and especially in the effects produced upon subjacent rocks by the stranding of icebergs. It was with much diffidence that he dissented from the opinion entertained by some eminent geologists, that this circumstance had any agency in producing the parallel grooves constituting so remarkable a feature in the rocks of New-England. Even assuming that in a former era the drifting masses of ice had pursued a uniformly direct course from north to south, though this might explain the general distribution of erratic blocks and bowlders, yet it appeared to him highly improbable that their grounding, and then being driven forward by the combined forces of wind and sea, could ever have produced the furrows in question. There is no reason why the oscillatory or semi-gyratory movement, should not then have followed such an accident as it does now; in which case, as at present, the tendency would be rather to obliterate all such marks, (had they previously existed,) and form a deep hollow, if passing over a yielding surface, or a confused scratching and grinding down of a rocky one. It had been shown, however, that the icebergs of the present day pursue a very irregular course, and although their general progress is truly from north to south, or the reverse, yet, impelled by varying winds and currents, they deviate widely both east and west of a meridional line. Did not this fact in some measure explain the difference pointed out by Professor Hitchcock as apparently existing between the line of direction observable in the distribution of bowlders, and that of the diluvial scratches? It had been suggested, that at the period when the drift was deposited, there was no Gulf Stream to affect the course of floating ice; but while this may be very true, it does not follow that there were no currents whatever. It struck him that to assume the production of our parallel grooves by the action of stranded ice, was to presuppose a state of things, a combination of circumstances, amounting to a physical impossibility.

Not only must it be taken for granted that there were no currents, or at least but one from the pole to the equator, and only one perennial wind blowing in the same direction, but the floating masses must either have been of such nicely-balanced proportions, and melted with such uniform regularity, and the waves must have struck them so exactly from the same quarter, as to have prevented any change of position; or they must have been in such numbers and so closely packed, as to preclude any oscillatory movement.

Was it essential to the explanation of the phenomena of drift, to assume that the distribution of bowlders, and the production of our so called diluvial scratches, were entirely the result of contemporaneous action? Might there not have been a period when the northern portion of our hemisphere was covered with glaciers resembling those of the Alps, during which the furrows were produced by their gradual and radiolinear advance, followed by one of drifting ice, (whether borne along with a sudden rush of waters, caused by a paroxysmal elevation of land in the vicinity of the pole, or floods resulting from a gradual melting away of the mass, he would not now pause to inquire,) depositing bowlders through its course, and by the stranding and grinding of large masses of which into beds of sedimentary matter or drift, were occasioned the singular contortions visible in portions of the clay strata?

If it could be shown that a sudden and violent rush of waters from the polar region had taken place, sweeping over the whole northern portion of this hemisphere, bearing along with it large islands of ice, denuding the hills and filling the valleys with drift, and eventually subsiding almost as rapidly as it poured southward, — would not this induce a belief that the remarkable, large, bowl-shaped cavities described in Professor Hitchcock's able memoir on the drift of New England, as existing on Cape Cod and elsewhere, might have been formed by the stranding and grinding of large islands of ice down into the recently deposited drift? It occurred to Mr. C. at once, when these excavations were alluded to by Professor Hitchcock, in connection with ice, that they might have originated in this manner, rather than from the deposition of matter around the melting ice, as suggested by that gentleman, — or they may have been produced by a combination of these two operations; the grinding and settling down of the stranded berg, excavating a hollow, while the earthy materials contained in it would be piled up around the sides as it dissolved. If we supposed a very large berg, of the pinnacled character, to have been left aground by the subsidence of the paroxysmal flood, and divided into several smaller ones, each forming a separate crateriform bed for itself, we should then readily comprehend the production of such a group of these cavities as was described by Prof. Hitchcock. Whether these suggestions were borne out by the geological features of the drift in general, was left for those to determine whose observation had been more specially directed to a study of those phenomena. Mr. Couthouy observed that he would merely repeat, that in relation to the production of diluvial, or to speak more correctly, glacial furrows, he had no preconceived views of his own to support; but that when he first heard them attributed to the grating of icebergs along the bottom, he was convinced, by the recollection of what he had personally witnessed of the action of ice under such circumstances at the present day, that this never would have produced such results. The parallelism and uniform direction of the striæ, appeared to him conclusive of a different agency in their formation. He felt persuaded that no person who had once seen the actual movements of a stranded iceberg, would ever afterwards entertain for a moment, the idea that such a cause would produce the furrows under consideration. He also thought it very problematical whether icebergs would, by their stranding, and being irregularly pushed forward by wind and wave, produce moraines, having much if any affinity with those resulting from the slow, regular advance of the Alpine glaciers.

He offered these suggestions with no small hesitation, fully sensible how presumptuous it might seem in him to venture a difference in opinion with those eminently distinguished geologists who had addressed the Association on this topic. They were, however, such as arose naturally in his mind while reflecting on what had passed under his own observation. The facts on which they rested were before the members, and so little was really known, so few had an opportunity of witnessing this part of the aqueo-glacial agency now going forward, he felt sure that they would excuse his having trespassed on so much of their time in submitting at least these facts for their consideration.

In conclusion, Mr. Couthouy remarked, that he had in this paper used the term *aqueo-glacial* to express the nature of the action of water and ice, in connection with the deposition of drift, rather than that of *glacio-aqueous*, proposed by Professor Hitchcock in his memoir, not merely for its greater euphony, but because he thought it more expressive of the relations of the transporting media, of which water rather than ice was the predominant, or at least the active agent, and therefore entitled to precedence in a descriptive phrase like this.

A communication was then read from Dr. Hale, inviting the Association to make use of the library and rooms of the American Academy of Arts and Sciences.

The Association adjourned to

Tuesday, 3½ o'clock, P. M. — Prof. Wm. B. Rogers was called to the chair, in consequence of the indisposition of the President.

Dr. Jackson exhibited drawings of the pot-holes described by him in the morning, and gave a further description of the same; and the discussion of the morning was carried on by Prof. Henry D. Rogers, Prof. Emmons, Prof. Hitchcock, Mr. Redfield, and the chairman.

Prof. Beck read a paper "on some Pseudomorphous or Parasitic Minerals of the State of New York," on which remarks were offered by B. Silliman, Jr., Dr. Jackson, and Prof. Emmons.

Mr. Vanuxem read a paper "on the Origin of Mineral Springs," which he followed by some remarks on the metalliferous ores found by himself in the State of New York, together with some observations in regard to fissures in rocks.

Association adjourned to Wednesday, 9 o'clock, A. M.

In the evening Prof. Silliman delivered a most interesting address on the "Progress of Geological Science in the United States," to the Association, in presence of the public, who had been invited to attend.

Wednesday, *April 27th*, 9 o'clock, A. M. — Association met pursuant to adjournment, Dr. Morton in the chair.

A letter was read by the secretary from Mr. Richard C. Taylor.

The Constitution, as reported by the committee on the Constitution and By-laws, was then read by the secretary. After several amendments it was adopted.

Resolved, That Prof. Silliman be requested to publish his address, read before this Association, in the American Journal of Science, as one of its articles.

After some remarks on the subject of drift, Prof. Emmons offered the following resolution, which was carried.

Resolved, That the subject of drift in our country receive still further examination from the committee, and that a further report be made at the next meeting of the Association. Objections to the views presented, and to the manner in which the subject has been treated by geologists in general, are, that many phenomena are confounded together; as, 1st, the washing up of ridges along the shores of lakes; 2d, those of glaciers; 3d, of icebergs; 4th, of alluvial beds; 5th, the accumulation of bowlders along what were ancient coasts; and 6th and 7th, pot-holes and slickensides. Icebergs do not necessarily act upon rocks when borne along, inasmuch as they are supposed to be defended by soft materials, as gravel, sand and mud; they explain merely the *distribution of bowlders;* and that their peculiar movements, when grounded, are not likely to form parallel grooves or scratches. The theory of a hemisphere of ice, capping the whole of at least the northern region, is objectionable, from the utter extinction of life, especially of molluscous animals, which must have been produced by it, but which does not appear to have happened, as there is an uninterrupted or unbroken series of them from the eocene to the present.

Resolved, That a committee of three or more be appointed, each to make a distinct report on the subject of drift.

Prof. Emmons, Prof. Wm. B. Rogers, Mr. Vanuxem, Mr. Nicollet, and Dr. Jackson, were appointed on the above committee.

Resolved, That all committees which have not reported this year, be instructed to report at the next meeting.

Resolved, That a committee of one be appointed to inquire, through all available sources, in regard to the influence of icebergs on drift. Mr. Couthouy was appointed on the above committee.

Prof. Locke read a paper on the ancient earthworks of Ohio. A discussion, followed some remarks of the chairman (Dr. Morton) on this subject, between Prof. LOCKE, Mr. NICOLLET, Dr. KING, Mr. HALDEMAN, Prof. SILLIMAN, Prof. HITCHCOCK, and Prof. BAILEY. Mr. Nicollet related several observations relative to the manners and customs of the Indians, made during a long residence in their country, having a bearing on the construction and age of these mounds.

Resolved, That a committee be appointed to examine and report on the subject of western mounds. The following gentlemen were appointed on this committee.

Prof. LOCKE, Mr. NICOLLET, Mr. JOHN H. BLAKE, Dr. ENGELMAN, Mr. S. P. HILDRETH, Prof. TROOST, and Dr. B. B. BROWN.

Adjourned to Thursday at 9, A. M., the afternoon being appropriated to the hearing of an address before the Boston Society of Natural History, by the chairman of this Association.

Thursday, April 28th, 9 o'clock, A. M. — The Association met according to adjournment, Prof. SILLIMAN in the chair. Proceedings of the former meetings were read and accepted.

Resolved, That Mr. JOHN L. HAYES be added to the committee on the subject of icebergs, and that he be requested to prepare a separate report.

The committee appointed reported an article relative to amendments of the constitution, which was adopted as a part of the constitution.

Resolved, That on Friday at 9, A. M. the Association proceed to the choice of officers for the next annual meeting, and also to fix upon a place for the same.

Prof. LOCKE read a paper describing a new instrument invented by himself, and which he called a *Reflecting Level and Goniometer*. He described a reflecting compass of his invention, and read a paper "on a Prostrate Forest under the Diluvium of Ohio."

Prof. HALL made some remarks on the wood found underneath the drift in Washington.

Prof. HUBBARD offered some remarks on the drift of New Hampshire, exhibiting a remarkable specimen of a bowlder of smoky quartz containing acicular crystals of rutile.

Resolved, That Prof. Hubbard be added to the committee on drift.

Dr. C. T. JACKSON read a paper "on the Tin Veins of New Hampshire," and exhibited specimens of the ore, both crystallized and compact, and an ingot of the reduced metal weighing three ounces, obtained from five ounces of the ore; also the accompanying minerals of the vein at Jackson, and specimens of the yellow blende of Eaton, the black blende of Shelburne, the reduced metal from each, and from the associated lead ore.

Prof. W. B. ROGERS adverted to the occurrence of oxide of tin in Virginia, associated with the auriferous quartz and other minerals of some of the gold mines. As yet he had discovered it at only a few localities. It is in the form of very small crystals scattered at wide intervals, and even where it occurs, is perhaps the rarest of all the metallic minerals found in and contiguous to the gold veins. In the two or three instances in which it was found in place, it was imbedded in a talco-micaceous slate, near its junction with the auriferous quartz. The minerals met with in the talcose and micaceous slates, which usually include the veins and beds of auriferous quartz, are auriferous, common, arsenical and cupreous sulphurets of iron, sulphuret of copper, carbonate of copper, sulphuret of zinc, sulphuret of lead, sulphur in minute crystals lining the cavities of cellular quartz, metallic gold, peroxide of iron, phosphate of lead beautifully crystalline, oxide of tin and oxide of bismuth, both exceedingly rare.

In connection with Dr. C. T. Jackson's remarks on the occurrence of sulphuret and other ores of zinc in New Hampshire, Prof. W. B. ROGERS mentioned that he had found the sulphuret of zinc sometimes, and the silicate (electric calamine) generally and very abundantly in the lead mines of Wythe Co., Virginia. The *latter mineral* often occupies a great part of the breadth of the vein, lying for the most part beneath the lead ore, sometimes as a sub-crystalline mass and sometimes in groups of small radiating crystals. The *sulphuret* is chiefly met with in nests and thin veins, in the sparry and magnesian limestone adjoining the lead ore, and is intermixed with crystals and small seams of galena.

Prof. Rogers added, as a fact of mineralogical interest, that besides the *sulphuret of lead*, these mines yield in some instances quite a large proportion of *carbonate*, of which beautifully pure crystalline specimens are by no means uncommon; and what is still more interesting, they furnish a very considerable amount of *red oxide* or *native minium*, with a small proportion of *yellow oxide*, both of which have hitherto been regarded as very rare minerals. From its resemblance to ferruginous earth or clay, this red oxide was until lately regarded at the mines as worthless, but is now highly valued for its productiveness in metal.

Dr. C. T. JACKSON exhibited a specimen of meteoric iron from Claiborne County, Alabama, in which he discovered chlorine, in the form of chloride of iron and nickel, in 1834.

Prof. J. B. ROGERS referred to some analyses of meteoric iron and meteorites recently made by him. A specimen of meteoric iron taken from a mass of many pounds weight in Grayson Co. Virginia, was found to contain 6.15 per cent. of nickel, and gave a very slight trace of chlorine. A meteoric stone from Georgia, made up of shot-like grains of nickeliferous iron, with slender flattened threads of the same mineral imbedded in a paste composed chiefly of silicate of magnesia and alumina, gave no indications of chlorine. The grains yielded 7 per cent. of nickel.

Prof. W. B. Rogers stated that he had examined a mass of meteoric iron from Roanoke County, Virginia, and was unable to detect in it the slightest trace of chlorine. A fragment of meteoric stone from Ashe County, North Carolina, examined at the same time, was found to contain a marked quantity of this principle, the presence of which, however, was accounted for by the fragment having been in contact with a bag of salt, as it was carried home by the person who found it.

Prof. Hitchcock read a paper "on a New species of Ornithichnite from the valley of the Connecticut river, and on the Rain-drop Impressions from the same locality."

After Prof. Hitchcock's observations respecting the bird tracks of the Connecticut valley, Mr. Lyell alluded to the subject of the cause of the present dip of the formation, expressing the opinion that it is due, in part at least, to an uplifting of the strata.

Prof. H. D. Rogers mentioned the reasons which had induced him to attribute the dip of the beds in the other great tract of this new red sandstone, or that which ranges southwestward from the Hudson, to oblique deposition. A uniform northerly dip of about fifteen degrees prevails entirely across the basin, even where it is twelve or twenty miles in breadth, and coëxists with a manifest shallowness of the deposit. This want of vertical depth is seen in several places in Pennsylvania, where denudation has exposed, in the interior of the tract, large patches of the older Appalachian strata, upon which this new red formation rests unconformably. No traces of dislocation occur to lead to the inference that the shallowness of the basin is deceptive, and that the present want of depth in the deposit has been caused by a succession of upthrows with denudation. The steady northerly dip is very rarely influenced, either in amount or in direction, by any of the numerous dykes of trap which penetrate the formation.

Prof. Rogers next mentioned facts which go to show that the formation of the Connecticut valley and the equivalent one of the Middle States, are in all probability, accumulations in two originally distinct estuaries. He mentioned as one evidence, the independent direction of the dip in the two basins, and stated that the absence of a parallel order of succession in the members of the two formations, tends likewise to strengthen this opinion.

Mr. Lyell conceived the steepness of the dip, which sometimes amounts to twenty degrees, but more especially its direction, — transverse to the course of the ancient estuary, to present a difficulty. Prof. R. endeavored however to show that the present dip might have been the original one, by suggesting, first, that there is evidence, in the nature of the materials of the great southern basin, for believing that they entered the estuary *laterally* on the outcrop side, by streams flowing from a country of decomposing, talcose, chloritic and hornblende rocks; secondly, that if the channel was near the same shore, the velocity of the tide might have prevented any horizontal deposition far out from the margin; and thirdly, that a gentle and steady *rising* of the region would, in conjunction with the proximity of the channel, tend to maintain both the slope of the sediment and the lateral advance of the shore which the hypothesis requires.

Mr. Benjamin Silliman, Jr., referring to the formation of the Connecticut valley only, considered a part of the present inclination of the beds to be the result of upheaval, connected with the outbursting of the trap.

Prof. W. B. Rogers made some remarks corroborating the views of Prof. H. D. Rogers in their application to the middle secondary or new red sandstone strata of Virginia and North Carolina. He described this group of rocks, consisting of shales, slates, sandstones and conglomerates of various tints of red and gray, as extending with some considerable interruptions in a nearly S. S. W. direction, entirely across the State of Virginia, and for some distance into North Carolina. With but a few local exceptions he had found the dip throughout this belt to be N. W. or N. N. W. Though destitute of the wide and prolonged ridges of trap met with in the corresponding districts of Pennsylvania and New Jersey, this region includes a great number of small dykes and knobs of trappean rocks, penetrating the sedimentary strata, but in no instance causing any well-marked change of dip in the adjacent beds. The materials of these strata Prof. R. stated to be very clearly traceable to the region of gneissoid and schistose rocks lying to the southeast of the tract, and in some cases, as in the limestone pebbles included in the conglomerate, could even be referred to the individual beds from which they had been torn.

He supported the opinion maintained for some years past by Prof. H. D. Rogers, that the inclination of the strata is not due to a tilting action subsequent to their deposition, but is the simple consequence of the influx of detrital matter from the southeast, and its deposition in a series of northwest-dipping planes. As greatly favoring this view he mentioned the fact generally observed in this belt throughout Virginia, that the strata become steeper in their inclination as we proceed towards the northwest; whereas, the reverse should have been expected from a force tilting them from a horizontal or gently inclined position into the present northwestern dips. This opinion he conceived, was still further confirmed by the appearance of the strata in some parts of the district, where, in consequence of the removal of the sedimentary rocks from a narrow space entirely across the tract, he was able to trace the beds from their outcrop nearly to the bottom of the trough in which they were deposited. In this case he found the inclination of the beds to continue unchanged downwards, instead of becoming more gently inclined towards the bottom, as might be expected on the hypothesis of an originally horizontal position with a subsequent uptilting movement.

Mr. REDFIELD spoke of fossil rain-marks of a very perfect character which he had observed with Mr. Lyell, at the quarries of new red sandstone near Newark, N. J. He also gave notice of the discovery of a new species of fossil footmark in the new red sandstone of Connecticut. The specimen which he had seen was found in the well-known quarries at Portland, (formerly Chatham,) by Mr. Russell, one of the proprietors, and is now in the possession of Dr. Barratt of Middletown. These footmarks are wholly unlike the Ornithichnites described by Prof. Hitchcock, some of which have been found in the same quarries; but they have some little resemblance to the *Cheirotherium minus*, which is figured in the Bulletin of the Geological Society of France.

Mr. Redfield also exhibited a new species of fossil fish from Sunderland, Mass.. which seems referable to the genus *Palæoniscus;* and also called the attention of the Association to a difference of structure in the *Palæonisci* of the Sunderland locality from those of Connecticut in the same formation; while the latter have a perfect resemblance to the fossil fishes of New Jersey. He had also discovered an apparent error in his own printed notice of American fossil fishes, in having named Sunderland as one of the localities of the genus *Catopterus*, as further examinations had led him to doubt on this point; although this genus is more common than *Palæoniscus* in the new red formation, both in Connecticut and New Jersey.

Mr. LYELL and Mr. B. SILLIMAN, Jr. offered some remarks on Mr. Redfield's observations.

Mr. JOHN L. HAYES, in explanation of the fossil footmarks in the sandstone of Connecticut river valley, gave some account of the existing species of birds most nearly resembling those supposed to have made those tracks.

As going to show the inclined position of the strata at the time when these impressions were made, Prof. W. B. Rogers called attention to a peculiarity in the form of many of these impressions, noticed by himself and Prof. H. D. Rogers in company with Prof. Hitchcock, during the last summer, and often remarked by Prof. Hitchcock on previous occasions. The feature referred to resembles the effect of a slight sliding of the foot in soft clay. It is seen in some of the larger footsteps, both those which point upwards and downwards in reference to the present slope of the rocks, and is even more conspicuous where the animal has been walking horizontally along the inclined surface, in which case there is a protuberance on the downhill side of each impression, as if, in virtue of the slope, the pressure of the foot had accumulated the soft clay in that direction. Adjourned to

Thursday, 3½ o'clock, P. M. — Prof. W. B. Rogers in the chair. A communication from Prof. Chester Dewey on the polished rocks of Rochester, N. Y., was read.

Dr. Locke exhibited about eighty colored casts of the fossils found in the western rocks, and offered remarks upon the advantages to be derived to geological science from the distribution of similar copies.

Mr. James Hall and Prof. H. D. Rogers offered some remarks on observations made in connection with Dr. Locke on the same subject.

Dr. King expressed the opinion that the fossils exhibited by Dr. Locke, were not generally the same as those common to the lead-bearing series of the upper Mississippi, and that from his investigations, which had been pretty extensive, he believed that the portion of the formation of that region in which the lead is found, overlies, and is very distinct from what is considered by Dr. Locke to be the *cliff* formation of Ohio. To this Prof. Locke replied that the fossils presented by him, were not presented as the fossils of that part of the cliff limestone, containing the lead ore; some of them were actually from the stratum overlying that ore.

Resolved, That the attention of the meeting be strictly confined to the reading of papers, during the remainder of the present session, and that no discussion be allowed thereon.

Mr. James Hall read a paper in connection with a section which he exhibited, of the rocks extending from Cleveland, Ohio, southwesterly to the Mississippi.

Prof. Locke offered some remarks, explanatory of Mr. Hall's opinion on the equivalency of the western formations.

Prof. Hitchcock read a paper on the determination of the silicified trunk of a tree found in the new red sandstone of Connecticut.

The Association then proceeded to the election of a standing committee.

Resolved, That this committee consist of the following gentlemen: Prof. Edward Hitchcock, Dr. Ducatel, Dr. C. T. Jackson, Prof. Lewis C. Beck, Mr. Lardner Vanuxem, Dr. J. B. Rogers, Prof. J. W. Bailey, Prof. John Locke, and Prof. B. Silliman.

Resolved, That Dr. King and Dr. David Dale Owen, be added to the committee on the western mounds. Adjourned to

Friday, *April* 29, 9 o'clock, A. M. — Association met pursuant to adjournment, Prof. Beck in the chair; minutes of the last meeting read; proceeded to the choice of officers for the ensuing year, according to the resolve of yesterday. The following gentlemen were unanimously elected: Prof. Henry D. Rogers, Chairman; Prof. John Locke, Treasurer; Prof. Oliver P. Hubbard, Secretary.

Resolved, That the next meeting of this Association be held in Albany, N. Y.

The secretary was requested to answer a communication from the National Institute at Washington, inviting the Association to meet in that city.

In consequence of the election of Prof. Locke to the office of treasurer, a vacancy was left in the standing committee, he being *ex officio* a member of that committee. Mr. John L. Hayes was elected in his place.

Prof. Wm. B. Rogers, Prof. Locke and Prof. Hitchcock, were appointed a committee to confer on the subject of the time of the next meeting.

Resolved, That the publication of the abstract of the proceedings of this meeting of the Association, be committed to the chairman and secretaries of the present meeting.

A communication was read from Mr. J. E. Teschemacher, containing "a description of the oxide of Tin, found at the Tourmalin locality of Chesterfield, Mass."

Prof. Beck read the title of a paper "on some Trappean Minerals, and the general Geological conclusions to be drawn from their History."

The committee on the time of meeting for 1843, reported the fourth Wednesday of April, which was accepted.

Prof. W. B. Rogers read a paper "on the Age of the Coal Rocks of Eastern Virginia." He described these strata as occupying parts of Chesterfield, Powhatan, Amelia, Henrico, and Goochland counties, and lying in basins of granite, the principal coal seam being separated by only a few feet from the floor of primary rock. In some places near the margin of the field, where alone they have been explored, the thickness of these coal rocks is upwards of eight hundred feet, but towards the centre of the principal basin it is probably somewhat greater. Throughout much of this depth they consist of coarse grits, often composed of the materials of granite so little worn as to present the aspect of this rock in a decomposing state. In this paper Prof. R. shows, on the testimony of fossils, and especially the vegetable impressions found in the grits and slates associated with the coal, that these rocks, instead of being, as had been hitherto supposed, of even older date than the great carboniferous formation of the West, and of Europe, belong in fact to a much later period, and correspond nearly, if not accurately, with *the bottom of the öolite formation of Europe.* The prevailing fossils are of the genera *Equisetum*, *Tæniopteris*, and *Cycadites* or *Pterophyllum*, and either agree specifically, or correspond nearly, with those of the *öolite coal of Brora* and the equivalent beds at Whitby and other places. Prof. R. laid much stress on this determination, as supplying one of the links in the geological series not hitherto discovered in this country, and as presenting a striking analogy with the abnormal developement of the lower öolite in certain parts of Europe. At the conclusion of the paper, Prof. R. stated that from the fossils he has discovered in a particular division of the new red sandstone of Virginia, he expects ere long to be able confidently to announce the existence of beds in that formation corresponding to the *Keuper in Europe.*

Prof. Wm. B. Rogers communicated a paper "on the Porous Anthracite or Natural Coke of Eastern Virginia." In this paper Prof. R. investigates the cause of the peculiar texture and composition of this material, and points out the forms of vegetation from which both it and the neighboring bituminous coal have been chiefly derived. From the position of the coke beds, as compared with those of the bituminous coal, and the frequent interlamination of the two, he proves that the non-bituminous character of the former could not have arisen from the effects of heat on a seam of bituminous coal, but must be ascribed to the thorough carbonization and dessication of the vegetable matter before it was *sealed in* by the overlying strata.

Prof. W. B. Rogers communicated a paper "on the Connection of Thermal Springs in Virginia with Anticlinal Axes and Faults." In this paper he gives a list of more than thirty thermal springs, having an excess of temperature over the ordinary constant springs of the neighborhood of from two to nearly sixty degrees, comprising all the distinctly thermal waters which he has thus far met with in Virginia. These are all situated in the Appalachian belt, and, *without an exception, issue on or near the line of an anticlinal axis or a fault — or near the contact of the Appalachian with the Hypogene rocks.* Prof. R. laid much stress on the fact that the warmest of these springs were generally those which issued from the lowest formations. Accompanying the paper were a series of short sections, illustrating the geological position of a number of the most interesting of these springs.

Prof. W. B. Rogers communicated a paper entitled "Observations on Subterranean Temperature made in the mines of eastern Virginia." In this paper Prof. R. gives the results of observations with the thermometer at depths varying from one hundred to nearly eight hundred feet, all indicating an increase of temperature downwards. Some of these results, procured under favorable circumstances, he considers sufficiently accurate to warrant an inference as to the rate of increase of the temperature with the depth in this region. These, it is believed, are the first observations of the kind made in the United States, and, if we except those of Humboldt in Mexico, the first in North America.

Prof. H. D. Rogers offered some remarks on the influence of pyrites on the heat of the strata.

Prof. Hitchcock read a paper entitled "Notes on the Geology of some parts of Western Asia, derived principally from the American Missionaries," and exhibited numerous specimens in illustration of his remarks.

Dr. Dana exhibited a copy of what was probably the earliest work on the geology of America, entitled "Beyträge zur mineralogischen Kenntniss des Œslichen theils von Nord America und seiner Gebürge von D. Johann David Schöpf," 8vo. 1787, presented to the library of the Boston Society of Natural History. Mr. Teschemacher was requested to report on it.

Mr. Couthouy read a paper "on various Icebergs as observed by him." *

Mr. James Hall read a paper "on Wave Lines and other

* Mr. Couthouy's remarks have been already given, pp. 49–59.

markings on the surface of rocky strata in New York and other places."

Association adjourned to half-past three o'clock, P. M.

Friday, 3½ o'clock. P. M. — Prof. SILLIMAN in the chair. The following gentlemen were announced by the standing committee as the local committee for next year. Dr. T. ROMEYN BECK, Prof. E. EMMONS, Albany, and Mr. W. C. REDFIELD, New York.

A letter from Mr. JAMES T. HODGE, relative to the distribution of State Reports, was read by the secretary.

A paper was read "on the Structure of the Appalachian chain, as exemplifying the laws which have regulated the elevation of great mountain chains generally;" by Prof. HENRY D. ROGERS, and Prof. WILLIAM B. ROGERS.

The authors divide their paper into two parts; Part I, being a description of the phenomena: Part II, a theory of the flexure and elevation of the strata deduced from the preceding features of structure.

Part I, embraces the following heads:

1st. A sketch of the physical features of the Appalachian chain, from New England to Alabama.

2nd. Predominance of southeastern dips, with an historical sketch of the previous explanations offered by other geologists.

3rd. Of the character of the flexures of the strata, and the law of their gradation in crossing the chain northwestward. Two or three new terms are here proposed for designating conditions of structure. The several prevailing forms of structure are then exemplified: (*a*,) normal flexures; (*b*,) folded flexures and inversions; (*c*,) flexures broken or passing into faults.

4th. Of the distribution of the axes in groups; remarkable parallelism of the axes in each group; great length of some axes; bending of axes; increasing interval between the axes as we advance towards the northwest.

5th. Descriptions of a series of sections across the chain, with a table of the northwest and southeast dips which they disclose.

Part II, treats of the following theoretical topics:

1st. The force producing the flexure and elevation of the strata, was compounded of a wave-like oscillation of the crust, and a tangential pressure towards the northwest.

2nd. Theory of the origin of the supposed subterranean undulations, and of the manner in which the strata became permanently bent.

3rd. Identity of the undulations of the crust with the wave-like motion of the earth in earthquakes. This latter shown to result from an actual billowy oscillation of the surface of the subterranean fluid lava.

4th. Of the geological era of the elevation of the Appalachian chain.

5th. Analogous phenomena of flexures ; axes in other countries.

A paper was next read by Prof. HENRY D. ROGERS, entitled "an Inquiry into the Origin of the Appalachian coal strata, bituminous and anthracite." It embraces the following subjects:

1st. A brief introductory sketch of the researches of other geologists in the same region.

2nd. The extent and physical features of the Appalachian coal region.

3rd. The character of the strata; (*a*,) rocks of mechanical or terrestrial origin; the laws of their gradation and distribution; (*b*,) rocks of chemical or marine origin, as limestones, &c.; the law of their distribution; inferences respecting the position of the ancient carboniferous sea and its coast.

4th. Of the coal seams, and the phenomena immediately connected with them; wide range of some of the beds; identified from basin to basin; ancient limits of the coal much more extensive; area of the great Pittsburgh seam, and law of its distribution: present and former areas of the coal strata computed.

5th. Of the intimate mechanical structure of the coal: inferences: persistency of the minor subdivisions of the coal beds inconsistent with the doctrine that the vegetable matter was drifted.

6th. Character of the strata which immediately accompany the beds of coal; prevailing nature of the under stratum; Stigmaria; different composition of the overlying rocks; these latter indicate a rapid motion of the waters, the under clay on the contrary a quiet subsidence of sediment.

7th. Beds of marine limestone in contact with the seams of coal.

8th. Theory of the origin of the coal strata; sketch of the discoveries and opinions of preceding writers; deficiencies in the hypotheses hitherto presented; condition under which the vegetable matter of the coal seams was accumulated; of the part performed by earthquake inundations in producing the mechanical strata; evidences of gradual depressions and risings of the coast of the carboniferous sea; indications of similar alternations of secular and paroxysmal movements of the earth's crust at all geological periods.

9th. Regular gradation in the proportion of volatile matter in the coal as we cross the Appalachian basins northwestward; phenomena connected with it; theory of the debituminization of the coal, and conversion into anthracite.

Prof. W. B. ROGERS made a few remarks on Thermal Springs, as relating to the foregoing subject.

Dr. A. A. GOULD, Dr. AMOS BINNEY and Mr. HALDEMAN, were appointed a committee to report on the geographical distribution of shells.

Some discussion on the subject of the publication of the Transactions of the Association followed.

Resolved. That Prof. H. D. Rogers, Mr. B. Silliman, Jr. and Prof. L. C. Beck, be appointed a committee to take charge of the whole matter.

The following gentlemen were invited to become members of this Association: Prof. Johnston, of the Wesleyan University, Dr. Barratt, Middletown, Ct., Dr. James Deane, Greenfield, Mass., Prof. Nichols, Union College.

Resolved, That the thanks of this Association be tendered to our distinguished chairman, Dr. Morton, for his services at the present meeting.

Resolved, That an invitation be given to European societies who may have the same objects in view as our Association, to send delegates to our next meeting.

Prof. Wm. B. Rogers expressed his feeling of great satisfaction at the unanimity and good feeling which had pervaded the present meeting, as well as at the straightforward devotion to science which had marked so strongly all the proceedings of its members. The Association adjourned to

Saturday, April 30th, 9 o'clock, A. M. — Association met pursuant to adjournment, Dr. Morton in the chair. Minutes of the last meeting were read.

Prof. H. D. Rogers presented some details in relation to the striated surfaces of the northeastern counties of Pennsylvania, and the adjacent districts of New York, proving, that while the scratches which abound on the summits of all the mountain ridges in that part of the Appalachian chain observe a nearly north and south direction, answering to their prevailing course throughout New England and the country of the lakes, those on the sides and bottoms of the valleys obey, with remarkable fidelity, all the local deflections which a body of moving waters would encounter among the ridges and valleys of this entangled range. In the neighborhood of the Wyoming valley, the summits of the mountains, elevated about two thousand feet above the sea, and one thousand five hundred above the valley, are covered with nearly parallel striæ, pointing a little west of south, but on their slopes, in the bed of the valley, these lines follow other directions conforming to the course which any obstructed inundation would pursue. Thus, near Wilkesbarre, the northern flank of the southern mountain, which was here exposed to the full brunt of the inundation, exhibits the grooves with a direction compounded of the general meridional one, and that of the deflecting mountain wall. High on the side of the ridge, the striæ ascend the slope obliquely, but nearer the base they are parallel to the medial axes of the valley. Near the lateral notch, in the northern mountain at Nanticoke, they point *toward* the gorge, showing that a portion of the current here came from a quarter south of east. A great northern wave would, so long as it submersed in its first impetuous rush the summits of the mountains, move forward regardless of the local inequalities of the surface, but after it had partially subsided, the long parallel ridges would present so many barriers to divide and locally deflect the now feeble remnant of the drainage. Reviewing the phenomena which he has observed, Prof. Rogers concludes that the striæ were produced by the friction of the overlying stratum of drift itself, urged into rapid motion from the north by one or more sudden inundations. From the absence near the southern border of the striated region of granitic, or other far transported northern bowlders, he infers that floating ice, while it may have been concerned in dispersing the detrital matter from the north, has had no agency in furrowing and smoothing the surfaces of the strata.

The same gentleman next adverted to the origin of conglomerates and other coarse mechanical strata, attributing them in many instances to the similar agency of the sea-wave produced by earthquakes. The wide and uniform distribution of some of the coarser rocks of the Appalachian basin, was appealed to in proof that they could have been spread out as we find them only by a sheet of water as broad as the entire margin of an ocean, breaking in successive sea-waves upon the land, and abrading and dispersing the fragmentary matter during repeated oscillations of the crust.

Prof. Rogers then added some remarks respecting grooved and polished surfaces at the contact of ancient secondary strata. He thinks he has seen unequivocal instances of these in Pennsylvania. Their production at periods when the earth's temperature was manifestly incompatible with the existence of ice, would seem to demonstrate that angular detrital matter, urged by water, is able of itself to score and polish the surfaces of rocks.

Prof. W. B. Rogers continued the illustration of this subject, by calling attention particularly to the evidences of ancient denudation and drifting action, so strikingly displayed along the place of junction of the Oriskany sandstone, (Formation VII, of the Pa. and Va. Reports,) and the subjacent limestones, (Formation VI.) In many districts the limestone has been irregularly denuded, and even to a great extent removed, and at the same time fragments of the limestone and fossils, water-worn and blended with coarse sand and gravel, have been accumulated to form the lower beds of the Oriskany rock. The rapid fluctuation in thickness of the upper limestones, as witnessed in Virginia, Pennsylvania and western New York, (near Black Rock, for example,) Prof. R. ascribed rather to the irregular force of the denudation, than to irregularity of thickness in the original deposit. He dwelt upon the epoch of the close of this limestone series, and the commencement of the overlying sandstone, as one of great interest in the history of our Appalachian rocks, marked as it is, throughout a great part of the Appalachian belt, by evidences of a sudden and great change in the physical conditions of the ancient sea, and by the proofs of attendant drifting and denuding action of extraordinary energy.

He contended that the grooved and worn surfaces of the limestone which mark the abrading action of a drift at this ancient period, together with the same phenomena observed in the rocks of other portions of the Appalachian series, as described by Prof. H. D. Rogers and Mr. Hall, bear so striking a resemblance to those more recent effects, which have given rise of late to such deeply interesting speculations, that it would seem unphilosophical to refer the two to *different* mechanical causes. He therefore maintained, that as in the production of these ancient phenomena of diluvium or drift, it can hardly be supposed that *ice*, either floating or in the form of glaciers, could have performed any part, since the existence of ice in the ocean at that period is scarcely conceivable, we are under no necessity of resorting to the glacial, or even the glacio-aqueous theory, in explanation of the more modern phenomena of grooved and striated rocks.

Resolved, That Mr. J. D. Whitney, Jr. be appointed a committee to be charged with letters from the Secretary to the various Foreign Societies, inviting their coöperation.

The standing committee nominated the Hon. Nathan Appleton, of Boston, and Prof. E. Emmet, of the University of Virginia, as members of the Association, and they were unanimously elected.

Resolved, That the thanks of this Association be presented to the Secretary and Assistant Secretaries, for the performance of the arduous duties assigned them during the present meeting of the Association.

Resolved, That the different State Geologists be requested to apply to the legislature of the States with which they are connected, for a number of copies of their Reports for the use of the Association.

Resolved, That Mr. JAMES HALL be added to the local committee of next year.

Resolved, That the thanks of this Association be presented to the Boston Society of Natural History for the use of their Hall as a place of meeting, and for the kind attention shown to the Association by its individual members.

Mr. COUTHOUY read some extracts from his journal, "on the wave-like undulations of the earth's crust at all periods of disturbance from the most ancient date to the present time," instancing some modern volcanoes.

Dr. MORTON, on resigning the chair during the remainder of the meeting, then addressed the Association as follows:

GENTLEMEN — Before we part, permit me to thank you in the most sincere and grateful terms for the honor you have done me in permitting me to preside on the present occasion. I can assure you that I have listened with entire satisfaction and instruction to the proceedings of this body, which will fully sustain the high reputation of those gentlemen who have favored us with their communications, and at the same time establish the character of the Association at home and abroad. I look forward with confidence to its widely increasing utility; and with the most earnest desire to coöperate in your future labors, and confident of your success, I again thank you for the distinction you have thus kindly conferred upon me.

Prof. LOCKE was chosen chairman during the remaining part of the session.

Mr. COUTHOUY continued his remarks on the range of the volcanoes of the South Sea islands, and in regard to the progressive movement of volcanic action in a fixed direction.

Prof. LOCKE offered some remarks in regard to the Oulophyllites found on the Wabash river; also on the diamond found in Indiana on ground near and below the coal.

Dr. AMOS BINNEY and Dr. A. A. GOULD were added to the committee on publication.

Mr. JAMES HALL exhibited sections on Lake Erie, showing broken strata with intermingled drift; he also spoke in regard to wood and bones found in the drift of various parts of the State of New York, particularly in the Genesee river, and in regard to the change which has there taken place in the channel of the river.

JAMES D. DANA, A. M., of the U. S. Exploring Expedition, was invited to become a member of this Association.

Prof. LOCKE, in resigning the chair, remarked: In parting with the members of the Association, I cannot refrain from adverting to the fine spirit of harmony and cordiality which has characterized the present meeting throughout all its transactions. To preserve so desirable a condition, it is of the utmost importance that we observe, in all our communications, the most delicate principles of justice to the previous labors and publications of others. It is not sufficient that we may plead that we have not read their productions; we *must* read them, and give credit in order to preserve each his own reputation. To give credit is to acquire credit, and to withhold it is to sink ourselves into disgrace.

I will only add, that my happiness has been vastly increased by the multiplied social attachments which I have here formed. And in this I presume I express the sentiments of all who have here had the privilege of taking each other by the hand, and of reflecting mutually that look of cordiality which is to be warmly cherished in memory's cabinet until we meet again.

Association adjourned to meet at Albany on the fourth Wednesday in April, 1843. Signed,

SAMUEL G. MORTON, *Chairman.*

CHARLES T. JACKSON, *Secretary.*

JOSIAH D. WHITNEY, Jr. }
MOSES B. WILLIAMS, } *Assistant Secretaries.*

CONSTITUTION AND BY-LAWS.

ART. I. The Society shall be called "THE ASSOCIATION OF AMERICAN GEOLOGISTS AND NATURALISTS."

ART. II. The objects of this Association are, the advancement of Geology and the collateral branches of Natural Science, and the promotion of intercourse between those who cultivate them.

ART. III. All those persons whose names have already been enrolled in the published proceedings of the Association, and those who have been invited to attend the meetings, shall be considered Members on signing the Constitution and By-Laws.

ART. IV. Members of Societies having in view the same objects as this Association, and publishing transactions, shall be considered Members upon subscribing to the Constitution and By-Laws.

ART. V. Persons not embraced in the above provisions may become Members of the Association, upon nomination by the standing committee, and by concurrence of two thirds of the members present.

ART. VI. The officers of the Association shall be a Chairman, a Secretary, and a Treasurer, who shall be elected at each annual meeting.

ART. VII. The Secretary may appoint two Assistant Secretaries to aid him in the discharge of his duties.

ART. VIII. The Association shall meet annually for one week; the time and place of each meeting being determined by a vote of the Association at the previous meeting, and the arrangements for it shall be intrusted to the officers and the local committee.

ART. IX. The Standing Committee shall consist of the Chairman, Secretary, and Treasurer, with nine other members present, who have attended the previous meetings.

ART. X. It shall be the duty of the Standing Committee to nominate members for admission, and to manage the affairs of the Association.

ART. XI. The Local Committee shall be appointed by the Standing Committee from among members residing at or near the place of meeting, and it shall be the duty of said committee to make arrangements for the meeting.

ART. XII. The expenses of each meeting shall be defrayed by an equal assessment on the members present.

ART. XIII. All communications to the Association shall be presented in writing, and upon them discussions may take place which shall not be reported; but the facts presented in such discussions may be reduced to writing by the persons communicating them, and they may then be handed in at a subsequent session, when they may be entered on the records.

ART. XIV. If communications are made, and notice is given that they are to be withdrawn for publication elsewhere, they may be read, but no discussion shall take place on them.

ART. XV. No article of this Constitution shall be altered or amended without the concurrence of three fourths of the members present, nor unless notice of the proposed amendment or alteration shall have been given at the preceding annual meeting.

NAMES OF THOSE WHO HAVE BEEN PRESENT AT THE MEETINGS OF, OR HAVE MADE COMMUNICATIONS TO THE ASSOCIATION.

HON. NATHAN APPLETON, Boston, Mass. 1842.
FRANCIS ALGER, Boston, Mass. 1842.
PROF. J. W. BAILEY, U. S. Military Academy, West Point, 1841.
PROF. LEWIS C. BECK, Rutgers' College, New Brunswick, N. J. 1840.
AMOS BINNEY, M. D. Boston, Mass. 1842.
JOHN H. BLAKE, Boston, Mass. 1842.
PROF. JAMES C. BOOTH, Philadelphia, 1840.
M. H. BOYÉ, Philadelphia, 1840.
C. BRIGGS, JR. Columbus, Ohio, 1840.
PROF. PETER A. BROWNE, La Fayette College, Pa. 1841.
JOSEPH A. CLAY, Philadelphia, 1841.
REV. HENRY COLMAN, Rochester, N. Y. 1842.
TIMOTHY A. CONRAD, Philadelphia, 1840.
JOSEPH P. COUTHOUY, Boston, 1842.
SAMUEL L. DANA, M. D. Lowell, Mass. 1842.
PROF. CHESTER DEWEY, Rochester, N. Y. 1842.
PROF. J. T. DUCATEL, Baltimore, 1841.
GEORGE B. EMERSON, Esq. Boston, 1842.
PROF. EBENEZER EMMONS, Albany, 1840.
EBENEZER EMMONS, JR. Williamstown, Mass. 1842.
ROBERT W. FORBES, New Haven, 1842.
JOHN. F. FRAZER, Franklin Institute, Philadelphia, 1841.
MARTIN GAY, M. D. Boston, 1842.
ROBERT GILMORE, Esq. Baltimore, 1842.
AUGUSTUS A. GOULD, M. D. Boston, 1842.
REV. ALONZO GRAY, Andover, Mass. 1842.
PROF. JOHN GRISCOM, Burlington, N. J. 1841.
S. STEHMAN HALDEMAN, Marietta, Pa. 1842.
ENOCH HALE, M. D. Boston, 1842.
PROF. FREDERICK HALL, LL. D. Washington, D. C. 1842.

EDWARDS HALL, Albany, N. Y. 1841.
JAMES HALL, Albany, N. Y. 1840.
RICHARD HARLAN, M. D. Philadelphia, 1841.
C. B. HAYDEN, Smithfield, Va. 1840.
H. H. HAYDEN, M. D. Baltimore, 1842.
JOHN L. HAYES, Esq. Portsmouth, N. H. 1841.
Rev. EDWARD HITCHCOCK, LL. D. Amherst College, Mass. 1840.
JAMES T. HODGE, Plymouth, Mass. 1841.
WILLIAM HORTON. M. D. Craigville, N. Y. 1840.
E. N. HORSFORD, Albany, N. Y. 1842.
DOUGLASS HOUGHTON, M. D. Detroit, Mich. 1840.
BELA HUBBARD, Detroit, Mich. 1840.
Prof. OLIVER P. HUBBARD, Dartmouth College, Hanover, N. H. 1841.
CHARLES T. JACKSON, M. D. Boston, Mass. 1840.
JOHN B. S. JACKSON, M. D. Boston, Mass. 1842.
R. M. S. JACKSON, M. D. Alexandria, Pa. 1842.
ABRAHAM JENKINS, Jr. Barre, Mass. 1842.
Prof. WALTER R. JOHNSON, Philadelphia, 1840.
HENRY KING, M. D. Washington, D. C. 1842.
BARON VON LEDERER, Washington, D. C. 1840.
P. LESLY, Jr. Philadelphia, 1841.
Prof. JOHN LOCKE, M. D. Cincinnati, Ohio, 1841.
CHARLES LYELL, Esq. F. G. S. L. London, 1842.
FRANCIS MARKOE, Jr. Washington, D. C. 1842.
OWEN MASON, Providence, R. I. 1841.
WILLIAM W. MATHER, Columbus, Ohio, 1840.
ALEXANDER McKINLEY, Philadelphia, 1840.
SAMUEL G. MORTON, M. D. Philadelphia, 1841.
J. N. NICOLLET, Baltimore, Md. 1841.
CHARLES H. OLMSTED, East Hartford, Conn. 1842.
Prof. ROSWELL PARK, Philadelphia, 1842.
HENRY C. PERKINS, M. D. Newburyport, 1842.
WILLIAM C. REDFIELD, New York City, 1841.
Prof. HENRY D. ROGERS, University of Pennsylvania, Philadelphia, 1840.
JAMES B. ROGERS, M. D. Philadelphia, 1842.
Prof. WILLIAM B. ROGERS, University of Virginia, Charlottesville, 1842.
ROBERT G. ROGERS, Philadelphia, 1840.
Rev. JOHN LEWIS RUSSELL, Salem, Mass. 1842.
Prof. BENJAMIN SILLIMAN, LL. D. Yale College, New Haven, 1841.
BENJAMIN SILLIMAN, Jr. Yale College, New Haven, 1841.
D. HUMPHREYS STORER, M. D. Boston, 1842.
RICHARD C. TAYLOR, Philadelphia, 1840.
J. E. TESCHEMACHER, Boston, Mass. 1842.
CHARLES B. TREGO, Philadelphia, Pa. 1840.
LARDNER VANUXEM, Bristol, Pa. 1840.
JOSIAH D. WHITNEY, Northampton, Mass. 1841.
MOSES B. WILLIAMS, Roxbury, Mass. 1841.

TRANSACTIONS OF THE ASSOCIATION.

NOTICE OF A MODEL OF THE WESTERN PORTION OF THE SCHUYLKILL OR SOUTHERN COAL-FIELD OF PENNSYLVANIA, IN ILLUSTRATION OF AN ADDRESS TO THE ASSOCIATION OF AMERICAN GEOLOGISTS, ON THE MOST APPROPRIATE MODES FOR REPRESENTING GEOLOGICAL PHENOMENA: BY RICHARD C. TAYLOR, OF PHILADELPHIA. *Read 9th of April*, 1841.

ON the 18th of June, 1830, I had the honor of presenting to the Geological Society of London, and of reading a concise description of two models and sections of part of the mineral basin of South Wales, in the vicinity of Pontypool.

On the present occasion I take the liberty of exhibiting to the Association of American Geologists, at their second annual meeting, a model of the western half of the Schuylkill coal-field, in Pennsylvania. This is, in all probability, the first geological model that has been constructed in the United States; as was, I believe, that of the Welsh mineral district, the earliest of its kind; and as such was received in the exhibition of the Society of Arts.* I have felt anxious, I may say ambitious, to introduce the first American geological model to this Association. It seems necessary to the occasion to make a few explanatory observations, and I desire especially to address some general remarks to this meeting, on the available methods of geological illustration.

Before proceeding to the descriptive details of the present work, and of the region which it represents, I would advert to the extreme applicability of the science of modelling to the purposes of geological elucidation.

During a somewhat active life, embracing thirty-six years of

* The gold Isis medal was awarded to the exhibitor in 1830.

occupations connected either with the superficial features of our earth's surface, in various climates, or with investigations of the positions of rock formations, the modes of representing the principal phenomena, and the different systems resorted to for practical illustrations, have, of course, been long and frequently under deliberation. The result, it need scarcely be added, is an increasing conviction of the vast superiority of that method which admits of showing the objects solidly, in relief; and according to their actual proportions, whenever practicable. I mean the process of modelling areas of country, in preference to any other method of representation; whether by drafts, diagrams, tables, maps, sections, or other customary means. Under this impression, and with a view to convey these sentiments in a useful direction, I have made some exertion to complete, for this occasion, a specimen of the art, illustrative of several hundred square miles of interesting country in the interior of this State; but have only, during the intervals of the present meeting of geologists, found time to prepare and commit to paper the following observations.

With the best assistance which art can confer, by means of horizontal, or vertical, or concentric shading, or by the most elaborate arrangement of lines upon a plane surface, to produce the effects of light, shadow, height, depth and perspective, such processes, it is universally conceded, fail to accomplish what is simply effected by modelling. If to these desiderata in geological illustrations, and to those other lines which are indispensable to topographical or local delineation, we add those which are intended to represent the courses and the inclination of strata, and the breadths and separate characters of formations, the difficulties attendant on lucid illustration are heightened, in any process short of modelling.

Whenever the scale, upon which a given area is protracted, is sufficiently large to permit an approximate correspondence between the horizontal and the vertical admeasurements, the effect is perfect. The utility of the work is enhanced, inasmuch as it combines the exhibition of both transverse and horizontal sections on the field of survey; and illustrates not only the external features and physical geography of the district, but enables the interior structure, the grouping of its mountain masses, the inclinations, bearing, direction, contortions and dislocations of the strata into which those formations and masses are subdivided, to be exhibited in a simple, yet very striking and appropriate manner. With the addition of superficial coloring, the pictorial character of the region represented, can be as accurately depicted as in a highly finished landscape. Perhaps even more so, inasmuch as the positions of all surrounding objects, and of all accessory details, are defined with geognostic accuracy in the one case, rather than imperfectly traced in the other, however experienced may be the hand and the eye of the artist. The interesting and accurate effect incidental to a picture, thus formed in relief, is apparent enough when the observer brings his eye to the level of any point whatever on the model; — the summit of a mountain, the point of a bluff, or the curve of a river, for instance, — from whence all that he needs in obtaining at ease and convenience a view of the surrounding scenery, is accomplished.

For topographical observations, for rapid reconnoissances, for tracing routes for rail roads, for canals, or for ordinary roads and communications, the model system presents facilities for numberless practical purposes, and may be the means of saving a great deal of preliminary labor and expense, on such occasions, in a mountainous or forest district.

In all such regions, it is common to adopt as the best, because they are the most natural and the most permanent, lines of demarcation, the elevated chains, the elongated ridges, the ranges of highlands or platforms which divide the sources of rivers and influence the descent of drainage; or to constitute the rivers themselves, as they flow between these ranges, the boundaries of local and territorial jurisdictions. All of these are particularly and necessarily prominent features in a model; and these, the most sublime and most imperishable monuments in all countries, have with propriety been selected as the most fitting for such conventional purposes. Had a model, however roughly constructed, been in existence to illustrate the physical geography of what is termed "the disputed territory" in the northeast, half a century of embarrassment and conflicting opinions, and local difficulties, might have been saved to the interested parties. It is not too late, even at this hour, to exhibit in this way, all the topographical characters of that region; to represent those great natural features, suggested for lines of international boundary. All the details applicable for this purpose are but now in progress of collection. From their arrangement we may expect to result the clearing up of existing obscurities; a more accurate construction of terms, and the adjustment of important points, now at issue.

Models are peculiarly adapted to the exhibition of geological phenomena. For ordinary convenience of transportation and portability, no doubt maps are best adapted, for the library, or for the use of the traveller. But for public and more enlarged objects, and for scientific institutions, the more permanent and ponderous form of representation, such as that we have now under consideration, does appear to possess stronger recommendations. We would desire to extend the principle so far as to introduce it in the final elucidation of State geological surveys; convinced that the greatest advantage would result from it. There exists no remarkable or insurmountable difficulty in thus exhibiting, in the distinctest form, the most prominent geological features of the States around us. There appears to be no practical or scientific reason, (pecuniary considerations aside,) why the results of those labors which have proceeded so successfully, and are still prosecuted so satisfactorily, in most of the States in the Union, by gentlemen of high professional eminence, a large proportion of whom are now assembled here,—there appears no reason, I remark, why the vast mass of facts which they have thus so industriously accumulated, should not finally receive this mode of representation. The capitols of Harrisburg, of Richmond, or of Albany, and other seats of local government, might be honorably adorned with instructive geological models of their respective States; and in due time, when the great work has so far proceeded in advancement, the Capitol of Washington itself might be enriched by one superb model, in which shall be concentrated those results which so much combined talent has brought to light and reduced to order, and the usefulness of which has been demonstrated.

The illustration of physical geography by means of models has long been practiced in the admirable representations of mountainous regions in Southern Europe, by skilful artists. Many of the European museums contain extremely beautiful models of Alpine districts. Some of these even embrace a large portion of Southern Europe; constituting, in fact, maps in relievo, elaborately executed and truly valuable as works of art. For the most part they are designed as pictorial representations of highly interesting regions; without particular reference to their geology, or to the interior structure and arrangement of their elevated masses. Although these much-prized models obtained a place in the English collections, as splendid specimens of a peculiar art, the application of that art to economic geology, and to kindred subjects, for which it is especially adapted, has been but little employed in England, and its introduction is of comparatively recent date. The geological model, for which the Society of Arts conferred their gold medal, in 1830, was the first which had been exhibited in that excellent institution. A recommendation to adopt the more frequent application of the system, has been occasionally urged by prominent geological authorities. Since the date referred to, two most elaborately executed models, on a very large scale, have been exhibited in London; the one represents the field and battle of Waterloo, the other depicts the beautiful lake scenery of the north of England; both of them the result of vast labor and singular perseverance. Those models which, in Germany and some other mineral countries, represent the internal economy of the mines and mining operations, belong to a class extremely useful, but different from that which has given rise to the present memoir.

We come now to the consideration of the model before us. In point of mineral value, of geological peculiarities, of statistical intricacy, and of highly picturesque features, the district here represented in miniature, yet with sufficient faithfulness as regards characteristic distinctness, has perhaps no equal, within a similar area, in America. Its approximation to the tide waters of the Atlantic coast, moreover, confers upon it a commercial value, in connection with the sources of industry and of remuneration for labor, manifestly within its limits. We are justified in adverting to these circumstances, because the useful results, and the beneficial application of science in economic geology, form legitimate objects of associations like that which I have the honor of addressing.

The area here illustrated comprehends seven hundred and twenty square miles; being in length forty-five miles, and in width sixteen miles. It extends in breadth from four miles above Harrisburg, northward, to Millersburg on the Susquehanna, at the junction of the Wiconisco railroad. In length it reaches from the western extremity of the Cove mountain, on the west side of the Susquehanna, to within eight miles of Pottsville. It comprises the two forks into which the Schuylkill coal-field separates, opposite to Pinegrove, in the Swatara region. The northern fork or branch extends to the Wiconisco Coal Company's mines at Bear Gap, and the southern branch stretches towards the Susquehanna in a southwest direction, to within about a mile of that river. The coal formation along several miles of the western portion of this lower fork, is reduced to a narrow ridge, which can scarcely be expected to contain coal to any valuable extent. Both the branches alluded to are bounded or enclosed by corresponding mountain ridges; the strata of which, composed of the inferior red shales, and of a numerous series of sandstones and conglomerates, underlie the coal measures and the upper red shales. The coal strata in these separate branches or basins dip, for the most part, to their respective centres.

The horizontal area is protracted on a scale of two inches to a mile; the data for which have been derived from a variety of public and local surveys. In the vertical scale we have been enabled to approach so near to the horizontal as two of the former to one of the latter; an approximation which is more close than is usual in such works. And here it may be permitted to apply some remarks on the construction of diagrams.

It has been customary with most geologists, and I believe almost universally with civil engineers, where the bases of their sections are considerably extended, to adopt a much larger scale for the perpendicular than for the longitudinal dimensions. Consequently, the diagrams so drawn, amount to absolute distortions, and manifestly convey very inaccurate ideas. The proportions of relative heights and lengths are thus so grossly caricatured, that they bear but distant resemblances to what is intended to be represented. The inclinations of strata are changed from moderate angles almost up to vertical; the altitudes of hills are stretched to the eminence of lofty peaks; rounded secondary mountains assume the form of attenuated spires; gentle undulations become craggy steeps, and the ordinary surface of a country is thus metamorphosed into a region harshly broken into pinnacled spires and Alpine crests, and steep and fathomless gulfs — a hideous burlesque upon the actual aspect of the district represented, or rather misrepresented.

In constructing geological diagrams I have, for some time, ceased to make any difference between the horizontal and vertical scales. At any rate I have endeavored, as closely as may be, to adhere to that principle. If the drawings be executed with delicacy they rarely require a deviation from the rule; and I would respectfully recommend an adherence to it, among my geological friends, particularly in relation to the State surveys, where comparisons of sections are continually needed. We shall then, and not till then, possess something like uniformity in the representations of similar things. So long as the distorting principle is tolerated, we shall continue to convey and to view every thing under a false medium, and shall describe objects under every shape but their real one. Geological sections, if drawn with suitable care, and with the nicety that such works demand, particularly if they be engraved rather than lithographed, may be made perfectly distinct at a very small vertical scale. Detailed sections of particular portions, on a larger scale, can readily accompany and elucidate the general section. The present writer has constructed sections of many hundred miles in this country upon a scale, both vertical and horizontal, or very nearly corresponding, as small as five miles to an inch, and yet has exhibited all important features therein. The system is clearly the right one, and ought to be followed. It is the only one, in fact, which can be made to exhibit the true inclination of the strata, the real bearing, position and magnitude of the formations and their relation to each other, and furnishes the means of measuring the thickness of those masses. In modelling also, although not always attainable, it would be equally desirable to approach as nearly as possible to the same rule.

I have dwelt the more strenuously upon these methods of illustrating geological phenomena, with a view to attract the attention of gentlemen who are about to place before the public, for the benefit and instruction of us all, the result of their respective labors in the field. I would take the liberty of earnestly soliciting their attention to a matter which we all admit is extremely desirable,—namely, uniformity in the process and modes of representation. Wherever it is possible, let similar scales be employed for the geological sections of different States. Wherever it is practicable, and to a very great degree it already is, let similar colors represent similar formations, wherever they occur. If at this stage we cannot yet settle that extremely difficult point, that "consummation devoutly to be wished," a common nomenclature, let us approach it as near as we can, by the use of common symbols, as a temporary substitute for a common language.

I think these are matters on which the present meeting might, with perfect propriety, enter. Let it be borne in mind that the accumulation of facts is one thing—a desideratum of primary importance, certainly. But the science of putting together those materials—the exemplification of those facts—to effect the purposes of geological elucidation, to reach the understanding, to impress on the mind and memory, is no mean part remaining to be performed. Let it be remembered that facts are comparatively useless without arrangement; that they are valueless if they are not presented to the senses in an intelligible and accurate form. The elements wherefrom to erect a geometric figure may be before us, but until we have truly constructed that figure from those elements, our impressions as to its form and proportion are necessarily vague and feeble. The materials wherewith to construct a house or a ship may all be prepared with strict regard to their individual dimensions, but as separate members they convey to us no idea of the actual form of that house or that ship. It is the art of the builder then to put together those materials;

and, in like manner, the geologist, or the geological draftsman, or the modeller, has to exercise his art, in putting together and exhibiting in correct forms, the details he has labored so hard to collect. Above all things, let him avoid distortions in drawing. It is incumbent upon those who undertake to enlighten and instruct others by diagrams, to exhibit those diagrams in true, and not in false proportions. The master can no more hope to convey to his pupil a right idea of a cube or a square, for instance, by representing in his diagram its height four or five times its breadth, than can the draftsman in our science, expect to convey correct notions of geological arrangement by a similarly defective process.

Returning to the model before us. The local *elevations* above the level of tide, have been ascertained at a sufficient number of points, particularly in the coal districts, to convey the prevailing characters of the country. A number of these heights, are marked on their proper sites upon the model. All of these were found by spirit level and positive admeasurements. The Pennsylvania canal on the east bank of the Susquehanna river, where it cuts through the second mountain, is three hundred and twenty-seven feet above tide level in Chesapeake Bay. The Swatara river, above Pinegrove, passes through the same mountain, thirty-one miles to the eastward, at the height of six hundred and nine feet above tide. The prevailing elevation of the ridges which form the north and south edges of the southern coal basin, is sixteen hundred or sixteen hundred and fifty feet above tide water. As a general remark, when casting a glance over the area here represented, we cannot but be struck with the comparative uniformity in their elevations, and the extensive maintenance of those levels along the crests of the ridges, when not broken by transverse fissures. The Blue or Kittatinny Mountain, the southernmost of these nearly parallel ranges, is probably the highest. The coal range is next in elevation, and there is some lofty ground, forming Short Mountain, between Peter's and Berry's mountain.

Geological Features.—Under this head we shall here be very brief; because that subject is not the primary object of this address; and because the region has received, or will receive, ample investigation by the State geological survey, with all the combined advantages resulting from the official resources, the science and the experience of its able conductor. The results of that great work it would be premature to anticipate. The positions of the various formations and of the respective members of the groups of strata, within these limits, have already been indicated in the annual reports of Professor Rogers.

In contemplating this region, it appears to us that its most interesting features are attributable to the undulating and broken or upheaved character of the formations, by which process some of them are repeatedly brought to the surface, in long, elevated ridges, and again dip at high angles and form basins which enclose or support the superior strata—the carboniferous series being of course the highest. These circumstances confer a remarkably picturesque character upon the scenery, particularly where these parallel ridges are intersected by the Susquehanna, the Juniata, and the Swatara rivers. No part of Pennsylvania is so rich in pictorial beauty as the borders of the noble Susquehanna, or has furnished so many subjects for the skill of the painter.

The spectacle here presented, by this river, cutting across in its singular passage, nearly at right angles, through so many ridges of extremely hard rocks, would of itself furnish a theme for geological speculation. Phenomena like these are well illustrated by the mode of representation we have adopted. The numerous cross fractures marked by the frequent gaps through the mountains and by the remarkable ramifications of the Swatara, in the Pinegrove coal region, could by no other process of exhibition be rendered so intelligible.

The Coal Formation.—It forms no part of the plan of the writer to encumber this communication with minute details. With regard to the southern branch, more especially, it is the less necessary, as they have been recently published, at considerable length, in the form of reports to the proprietors of the soil.* What re-

* Vide Report on the coal lands, mines, &c., of the Dauphin and Susquehanna Coal Company, by Richard C. Taylor, President of the board of directors. Report of the geological examinations, &c. of the Stony Creek Estate, in Dauphin and Lebanon counties, by Richard C. Taylor. Philadelphia, 1840.

mains to be added here, under this head, will occupy a brief space.*

Ranging along the southern margin of this coal-field, appear nine principal transverse sections, "gaps" as they are locally termed, which cut through Sharp mountain. Through these ravines, many hundred feet in depth, the drainage of the coal area descends southward; and by the same avenues the highly inclined coal seams are intersected. The height at which these coal seams can now be reached within the gaps, without expensive tunnelling, varies from eight hundred to eleven hundred feet above the level of the sea; and as the summit attains an elevation of sixteen hundred and fifty feet, there are therefore from four hundred to eight hundred and fifty feet, measuring perpendicularly, of coal, capable of being worked, above those points of intersection.

The number, thickness, compactness and density of these coal seams increase as we pass eastward along the counties of Dauphin, Lebanon and Schuylkill. At the same time, and in a corresponding degree, or rather in a reverse ratio, the amount of bituminous and volatile matter, contained within the coal, diminishes; passing from a bituminous or semi-bituminous coal, which yields a bright blazing fire, and at some points is convertible into coke of good quality, to a compact anthracite, on the borders of Schuylkill county. This fact is exemplified in the series of analyses made on behalf of the proprietors and published in 1840, and subsequently by another series, recently embodied in the State geological report. The prevailing breadth of this southern fork, measuring from red shale to red shale, is about a mile; except towards the western termination, where it is only about one thousand feet to one thousand and two hundred feet wide, for three or four miles. In this range, the lower conglomerate, interposed in great thickness towards the eastern extremity of the Schuylkill coal basin, between the coal beds and the red shale, has thinned out and at some points appears to be altogether absent. The

* At the request of the author, we have, in printing the memoir, omitted many details which were embodied in the original; because without the assistance of maps and diagrams, they could not be rendered sufficiently intelligible to the reader.

greatest amount of coal which has been proved at this branch, is at Blackspring gap, where eight southern and seven northern seams have been explored, the aggregate thickness of which is ninety feet.

Passing over to the *northern branch* of the main coal-field, a fine series of beds occurs, some of them being of considerable thickness. The anthracite here is of excellent quality. From the Swatara region eastward for several miles, there has been but little exploration of the numerous coal seams known to exist there; there being no convenient mode of communication, by canal or railroad, completed in that quarter. Argillaceous carbonate of iron, in beds and detached masses, prevails in this coal region; to what extent, however, we cannot say, as their investigation has hitherto been but a secondary object.

The foregoing notes are, it is conceived, sufficiently explanatory of the prevailing characters of the district. Did it possess no other peculiarity or attraction than that derived from the remarkable arrangement, or rather derangement, of the formations which it comprises, it might still claim your attention, as an area of high geological interest. Viewing it with reference to its growing importance as a mineral country, favorably circumstanced, we have little cause for apprehension that the labors of the artist have been employed on a barren and profitless field. Already have nine or ten chartered companies for coal and mining operations located themselves there. Already several furnaces and forges have been established in its vicinity. The Pennsylvanian, the Wiconisco and the Union canals, traverse within its limits. Two or three railroads are already in full communication with its collieries, and charters for five or six others have been procured from the legislature. As relates to the region we have been considering, we are but on the threshold of improvement. The industry of man has but recently been put in requisition within its borders. But experience has already informed him that the once despised, chaotic, impassable wilderness, teems with treasures more precious to him, perhaps, than gold. The labors of the geologist, be they local or general; be they for private or for public objects; for individuals, for associations, or for the community at large,—cannot fail to develope new and beneficial results wheresoever directed, in such a field. To have had some share in the attaining and the distribution of this knowledge, and to have contributed any aid to the great cause of economic geology, is a gratification which is worth no small exertion to acquire. It has proved, let me add, in all sincerity, the strongest inducement to perseverance in the work now before the Association.

At the request of some members of the Association, I have annexed to the foregoing memoir a few illustrative sections, constructed on a variety of small scales, with the intention of exhibiting the practicability of using even minute vertical scales, in geological demonstrations. They are as follows: [Plate IV.]

Fig. A, represents a section whose horizontal scale is three miles to an inch, and the vertical scale 5280 feet to the inch, being in fact in the proportion of 3 to 1. This, although less distorted than is occasionally the case, it being easy to point out examples where the proportions are 6, 8, and 10 to 1, is drawn to show the contrast to the section B beneath it, where the proportions are equal, the horizontal line and the area illustrated being similar.

Fig. B. Section at three miles to an inch, both vertical and horizontal, of the same ground as Section A, and in fact a transverse section of a model, which has been described in the foregoing paper.

Fig. C. Section protracted at four miles to an inch, both vertical and horizontal. It shows the position of two of the detached Pennsylvania bituminous coal basins.

Fig. D. Section at five miles to an inch. Here there is a trifling increase, amounting to one half only, in the vertical scale, viz. 1½ to 1. It also exhibits two detached coal basins in Pennsylvania.

Fig. E. Section at two miles to an inch, on equal scales. This projection is sufficiently large to admit of characteristic details. It is a profile of the Alleghany mountain, descending eastward; also in this State.

As I have not conveniently at hand, examples of sections having the altitudes above tide level, drawn by other authorities, it was necessary to resort to the materials which happen to be in my possession, and for the most part prepared from personal observation. I hope they are sufficiently accurate for the purpose designed.

To render these experimental drawings more useful for comparison, I have inserted Professor H. D. Rogers's numbers of the respective formations. With regard to the colors adopted, they are not proposed as standards, but are simply those which I have been accustomed to employ; differing very little, I perceive, from those used by the gentleman last mentioned.

Before closing this subject, permit me to allude to the new geological map of England and Wales, by Mr. Greenough. As a finished specimen of art, it is probably the most beautiful production of the age, and may, with great advantage, be consulted, for the extreme clearness of its details.

Observations on the Secondary and Tertiary Formations of the Southern Atlantic States; by James T. Hodge. With an Appendix, by T. A. Conrad.

During the last year I spent a few months in making a tour on horseback through parts of the Southern Atlantic states. My object was to obtain from my own notice a general idea of a large portion of our country not familiarly known; but so rapidly did I pass through it, that my notes are crude and imperfect. From the investigations of Mr. Conrad, to whose instructions I am much indebted, the accompanying lists of fossil shells, which I there collected, were made out, and a few new species are now added to our catalogue of the tertiary fossils.

Until I arrived in the southern part of Virginia I was unable to see much of the "marl beds" of the tertiary, owing to the snow and ice that covered the ground. I found, however, that the marl extended all along the eastern section of the State, and that it was extensively used as a manure by the planters. On the Rappahannock, seven miles below Fredericksburg, the bed is at least ten feet thick, and so conveniently exposed that vessels might come alongside and load with it, if it were important enough to transport. It here abounds in shells, and also contains teeth of sharks, and fossil bones. Nearly all belong to extinct species, and the genera besides are those most common to the lower tertiary. The fertilizing properties of the marl appear to depend almost entirely upon the carbonate of lime afforded by the slow and long continued decomposition of the shells; it contains more or less of the green sand, but in too small proportion to add much to its richness; and the quartzose sand and mica that constitute the remainder of it can be of little service. The effect of this marl upon the cotton and clover is superior to that of any other manure, but then it is put on at the rate of seven hundred bushels to the acre, so that the surface of the fields is covered. Weeds are said to be killed the first year, but to come up luxuriantly afterwards, and clover appears spontaneously where none would grow before. In Caroline and Hanover counties, on land that would yield only three barrels of corn (fifteen bushels) to the acre, from ten to fifteen barrels have been obtained after one generous application of the marl. On the Pamunkey river is a beautiful plantation, regenerated from the old and exhausted tobacco lands; an example of what the Virginia soil once was, and what it may be again, if treated with the skill and enterprise which characterize Mr. William Wickham, the proprietor of this place. He has used the marl for eighteen years, applying it once profusely, eight hundred bushels to the acre. The bed here varies from ten or twelve feet to not more than two or three. It is often cut through, as if by a stream, and the space afterwards filled up by the ferruginous sand which overlies the marl bed.

In those tracts of country not cut through by large streams, as Prince George county, the marl is obtained with great difficulty, pits being dug that constantly fill up with water, which cannot be kept out even by expensive pumping. Still it is in great demand, the planters digging it in the winter months, when their hands are least occupied, and then carting it over the fields, where it lies in heaps ready to be spread in the spring. The lands in this county are generally stiff and clayey, and would be benefited by a free application of common sand, as well as of the marl. From these heaps I collected a great variety of fossil shells, enough to show that the deposit belongs to the same formation with that which I afterwards traced through North Carolina, but the specimens never have arrived from Murfreesboro', N. C., where I left them. This is the case also with many

I collected at Murfreesboro', on the south side of the Meherrin river. Some brooks have cut deep into the sand hills on which the town stands, and have distinctly exposed the marl; while from the bed they have washed out a profusion of fossil shells, chiefly *Pectens* and *Ostreæ.* Not far above the marl is a stratum of stiff, red clay, alternating with layers of sand. A bed of this character I have noticed in a similar position throughout a great part of the southern States; at Richmond, Va., it is very conspicuous near the summits of the hills, as well as in the southern part of Sumter district, S. C.; and in many places in Georgia, near the Savannah river, it is well exposed. It is accompanied by white clay, and sometimes by layers of gravel. From its position only on high hills, and want of fossils, I consider it to belong to the diluvium spread over the country after its elevation above the sea, most of which has been subsequently washed and worn away by long continued degradation.

Near the Roanoke, some miles above Williamston, I observed the marl by the road-side, and although it was hard frozen and nearly covered with snow, I recognized in it many individuals of our common recent shell, the *Venus mercenaria.* This is a very poor part of North Carolina; the land is quite flat and sandy, and during the winter season one frequently rides for miles through water several inches deep, by which the roads are flooded. The principal growth is of pitch pine, from which a great deal of tar and turpentine are made. The woods along the roads present a singular appearance, every tree being half stripped of its bark to the height of seven or eight feet, and the exposed surface bleached by the white turpentine oozing out. A little cavity is hollowed out at the base of the trunk, into which most of the turpentine runs, and the remainder is scraped off and put into barrels. The tree dies and becomes fat pine. This is burned in pits, as wood is for charcoal, and the tar runs out upon the carefully prepared clean floor. North Carolina tar is inferior to that made in Norway, owing probably to less pains being taken in the preparation. It is sent principally to the north, where it sells for about a dollar and a half per barrel, but the makers receive only ninety cents, out of which they pay twenty-five for the barrel.

In the very western part of Jones county, I first met with the limestone of the secondary formation. It is on the plantation of Mr. Humphreys, at the heads of New river and Trent river. The rock lies in a heavy ledge on the borders of a swamp; its surface is much worn and ragged. It is of a straw color, and apparently of good quality for making lime;—on submitting a piece to chemical examination, I find it as good as the limestone of this formation usually is. It yielded in one hundred parts,

Water, - - - - - -	1.00
Silica, - - - - - -	5.60
Iron and al., - - - - -	5.60
Carb. lime, - - - - -	87.00
Carb. mag. - - - - -	trace
	99.20

Several springs come out at its edge, which bring up small fossil shells and pieces of coral. Among the shells, which are generally very imperfect, may be recognized the *Pecten membranosus*, a *Cardium*, and others common to the same formation in New-Jersey. The water seems well adapted to the recent *Planorbis trivolvis*, *Physa heterostropha*, and *Paludina integra*, which inhabit it in profusion, and also to the luxuriant water-cresses, which equally abound in it. Around the limestone is a deposit of calcareous marl of a light yellow color, affording a very convenient and rich natural manure; but it has been entirely neglected as well as the limestone, the little lime required for the country being brought from Thomaston, Maine, although they have enough of the rock, wood at the expense of cutting it only, and a suitable sandstone for kilns, scattered through this region. This stone belongs to the same formation, and has been used sometimes for making millstones. Having fortunately some plans of kilns with me, I was happy to leave them, with the advice that the people make the attempt at least to supply themselves with their own lime.

Not far from this place, is that interesting locality in Duplin county, called the "*natural well.*" It is two miles west of the rail-road, (forty-seven miles from Wilmington,) on the road from Kenansville to Elizabeth, Baden county. Before reaching it, one may notice by the side of the road a large sink-hole, fifteen feet deep, overgrown by trees and bushes; a little beyond this, a path turns off to the left to the cabin of a Mr. John Smith, within two hundred yards of which, in the woods, is the well. It is a large circular basin, about twenty yards across, and sixteen feet deep to the surface of the water; its banks are nearly vertical, although the strata are entirely obscured by the loose sand, trees and bushes that have covered them, excepting in one narrow spot, where a correct section may be obtained and specimens collected. The soil, which is sand and yellow loam, a little clayey at bottom, is from three to four feet thick. It rests on the shell marl, which is about four feet thick, and under this is a tough blue clay from six to eight feet thick, overlying a sandstone like the clay in color, the lowest visible rock. The marl consists entirely of shells, and fragments of shells, with a very small quantity only of fine white siliceous sand. The shells are of a great variety of species belonging to this formation, and they lie promiscuously together in great confusion; single valves of the bivalves are more frequently found than the two together, and even the stronger univalves are most often seen in fragments. So abundant are they, that in cleaning out some of the larger shells a great number of small and more perfect specimens were found in their interior, and added to my collection. A *Pectunculus quinque-rugatus*, in particular, enclosed between its two valves a multitude of shells and fragments closely embedded in a fine, clear quartz sand. The contents when picked out occupied a space full twice that in which they were so closely packed. Although the diameter of the Pectunculus was only two inches and one fourth, there were in it a *Cytherea reporta*, beautifully preserved with its natural polish, one and one third of an inch long, and itself filled with other smaller shells and a purer sand than that which surrounded it — several small *Ostreæ Corbulæ*, and duplicates of twenty or thirty other species. There are, as seen by the accompanying catalogue, about eighty species found at this locality. Of these, twelve are recent, and twenty at least heretofore undescribed. Some yet undetermined remain in the hands of Mr. Conrad, and of these only the genera are given. The *Oliva idonea* has been previously described by Mr. Conrad; it is one of the most beautiful shells found here, being finely preserved, and most of the specimens not having lost their natural polish. The people living in the neighborhood know them by the name of "key shells," from their procuring them to attach to a bunch of keys. The cones are of the species *adversarius*, so named from their being nearly all reversed; one of mine is the only exception known. The bivalves are only occasionally met with entire.

It is remarked that the water in the well never varies in freshets nor droughts, and tales are told of ineffectual attempts having been made to sound it, and of a strong current setting through it, sucking down whatever is thrown in. That there is a current I doubt not, it being nothing unusual for a stream of water to sink suddenly under ledges of limestone, as at the Eutaw springs in South Carolina; and the limestone of the secondary formation I believe to be not far below the surface of the water, perhaps directly under the blue sandstone at the surface, which is very likely the upper rock of that formation, and the blue clay the lowest of the middle tertiary, as it often is, (the lowest tertiary is wanting in this part of the country.) The limestone of Jones county is not far off, and such sinks as these are frequent over limestone beds; in Georgia they are called "limestone sinks."

With my vallise and saddle-bags well stored with specimens, and a keg full strapped behind the saddle, I proceeded to South Washington, on the way to Wilmington. In this neighborhood I discovered again the secondary formation on the northeast banks of Cape Fear river. The rock is a blue sandstone, containing the characteristic *Exogyra costata*, *Belemnites*, *Plagiostoma pelagicum*, *Anomia ephippium*, &c. The existence of this rock between the tertiary deposits on the east and the west, seems to indicate an inticlinal axis here, which extending north, accounts for the elevation of the secondary throughout Jones county, and the broad extent of country on each side occupied by the tertiary marls. The axis must be low, and the dips very gentle, causing at most a slight undulation of the strata.

To the east of South Washington are large tracts, called bays and swamps, one of which, called on the map Angola Bay, was described to me by one who had crossed it. After traversing its margin, which was a broad swamp covered with thick trees and bushes, my informant and his companion came out upon an open heath, spreading as far as they could see, and destitute of all vegetation, save a thick covering of moss and a few scattered bushes. Through this moss they travelled on with great difficulty, plunging in at every step nearly knee deep. Procuring a pole from the trees on the border, he sunk it down eight feet into the mud without finding bottom. The moss and mud of these swamps would thus seem to be those always due to *peat* swamps. At night they reached an island in the swamp with a few trees upon it. Here they remained till morning, and then continued their course across, and reached the other side about noon, greatly fatigued. He thinks they are called "bays" from the quantity of bay trees that grow around them. Holly Shelter swamp is similar to this. These swamps remind one of those in the southern parts of Georgia, the islands of which were once inhabited, according to an old Creek tradition, by a superior race of beings, whose beautiful women, called "daughters of the sun," occasionally condescended to help out the poor bewildered traveller, lost in their intricacies, but who, with their houses on the islands, were never to be found by man, though eagerly sought after.

At Wilmington is another interesting locality, where not only the tertiary marl corresponding to that at the natural well is found, but the secondary sandstones and conglomerates below it are well exposed on the banks of Cape Fear river. The lower tertiary is wanting, and this marl bed, which is from two to three feet thick, is seen resting upon the sandstones, containing shells belonging altogether to the upper secondary formation. Above the marl, and resting on it, the upper stratum observed is of sand and loam, containing a few layers of small white pebbles. The marl is nearly as prolific in shells as the same formation at the natural well. The species, however, are not the same, as will be seen from the appended catalogue, (p. 106.) More than fifty species were collected, of which eight are recent, and those in italics new. Comminuted shells and fine sand form the marl stratum, and these are either converted into a solid mass not easily broken, or remain unconsolidated. The sandstone beneath is in one place a compact siliceous mass, but a little way off it changes to a coarse pebbly rock, consisting of small, rounded quartz pebbles of a dark color; and then again it becomes so calcareous that with proper care it might be burned to tolerable lime. The pebbly rock or conglomerate contains shells, and corals, and small sharks' teeth, in abundance. Large teeth are rare, as are bones, which are said to have been found in it. The shells themselves have generally disappeared and left only the casts: these, though very abundant and perfect, render it extremely difficult to determine the species. The genera are principally *Cypræa*, *Cirrus*, *Gryphea*, *Ostræa*, *Anthophyllum*, *Nautilus*, &c.

The proximity of this locality to the wharves and the town of Wilmington, would render it easy for strangers to obtain specimens thence. The marl is not here esteemed as a manure, probably because the soil is so sandy that the shells must decompose very slowly in it. By first applying large quantities of clay to it, and then the marl, no doubt very beneficial effects would result.

To the south of Wilmington I noticed the marl again on Little river, near its mouth, just over the boundary line in South Carolina. The shells closely resemble those at Wilmington, the most abundant being large Arcas; but they were all tightly cemented together by a ferruginous cement, forming a solid ledge on the edges of the water. This is the farthest point to the south where I observed this deposit; but I was told it occurs again on the Waccamaw river.

In treating of the tertiary formations of our country, I have preferred using the conventional names adopted by Mr. Conrad, of upper, medial, and lower tertiary, to those of pliocene, miocene, and eocene, applied to similar formations in Europe. The former merely indicate relative position, and are therefore sufficient at present; the latter imply a relative proportion, of course not very exact, of extinct and recent shells; and though our own formations may now each give about the same proportion with the English formations, still when two hours' work may discover more than twenty undescribed species in one locality, besides some recent species not before noticed in the formation; and when our knowledge of the living shells of our coast is so imperfect, it certainly proves that the adoption of these new names would now be hasty. It would be at once taking it for granted, (as it is certainly not proved,) that our strata will be readily divisible into the same three formations as those of Europe; and all difficulties, if any are hereafter encountered, will be too apt to be made to bend, or to be neglected, for the sake of keeping to this favorite but unproved system of classification. This subject, I hope, will be more fully discussed by Mr. Conrad, and sustained by more complete details than I am able to furnish.

At the locality last mentioned, near the boundary line, are found through the fields singular deposits of oyster shells, each extending over several feet square and about two feet deep. No account is preserved of the time or cause of these collections. They were made centuries ago, probably by the Indians. Corn does not grow well by these heaps, at which I was rather surprised.

There is a well-known locality of the secondary limestone at the Eutaw Springs, near Nelson's ferry over the Santee, in the western part of Charleston district. The striking similarity of this rock to that in Jones county, North Carolina, first attracted my attention. Like it, the limestone rose above the surface in heavy ragged ledges, here at least fifteen feet high; it was of the same light yellow color, and contained similar fossil shells. Similar springs too rise among the ledges of the rock, and they contain the same recent shells, and water-cresses in greater abundance. But the water, I noticed, was lukewarm, and one of the largest of the streams, after running only about fifty yards, suddenly disappeared under the limestone, and was no more seen. The rock does not contain a great variety of fossil shells: the most abundant are some large Ostreæ, of what species I know not, the specimens being lost. On this account, too, I cannot speak so decidedly as I wished to have done of the quality of the limestone, which ought certainly to be of some practical importance, being on a river navigable by steamboats, and in a region where lime bears a high price and wood is very cheap. A little enterprise and skill only are requisite to create an extensive business here in the manufacture of lime. But though its good effects as a manure force itself upon the notice of those who use the adjacent fields, still no attempts have been made to extend its use further than nature has seen fit to spread the rock, and the calcareous deposits formed from it.

So on the Edisto, in Colleton district, this rock is equally available, and equally neglected; and though lime enough might be made on these two streams to supply the whole of the eastern parts of South Carolina and Georgia, at an expense not exceeding fifteen cents a bushel, yet the inhabitants prefer to import their lime from Thomaston, Maine, and pay at Charleston two dollars per cask, or when brought up to the neighborhood of these vast quarries it sells for three dollars per cask! In Chester county, Penn., while on the geological survey of that State, I have seen lime made and sold for *ten cents* a bushel, where the natural facilities are no greater than here. And when on the same business in Maine, and employed at Thomaston in obtaining the statistics of the lime business, I came to the conclusion that the southern States must be remarkably deficient in limestone; that notwithstanding the difficulties the Thomaston people had to contend with, in the high price of fuel, a bad harbor, that frozen up one third of the year, and their remoteness, still they managed to monopolize the lime business of the Atlantic coast, of the Gulf of Mexico, and up the Mississippi to Natchez. The average cost of a cask of lime at the wharves at Thomaston, was, as near as we could estimate it, about seventy cents, and this included twenty cents for the cask. But unfortunately the term "cask" represents no definite measure. By law it should hold "forty gallons," five bushels, but every mason of whom I have made inquiries, and who has measured them, says their capacity is continually changing;

that most of them contain *less* than a common flour barrel, and that *three bushels and a half* is probably near the average measure of their contents. Their large size is made up by enormously thick staves, and heads about an inch thick, and frequently large empty spaces remain in the cask. Yet for this meagre amount of lime, the people of South Carolina are willing to pay a sum for which they themselves might make full *eight times* as much; and by thus rendering it cheap, the labor lost to their favorite crop would not be missed, when thereby a bale of cotton to the acre would not be considered a maximum product, nor *two* ears of corn to each of the widely separated hills a subject worthy of remark.

The prejudice of workmen — their not liking to use a different material from what they have been accustomed to — is one reason why the Thomaston lime has successfully competed with all other lime made on the Atlantic coast. The name of that is favorably known and deservedly so, and it will sell when another equal to it from another locality will not bring even a very inferior price. There was a remarkable instance of this a short time since in New York, some excellent lime from Rhode Island hardly finding a market at any price. Most of the Pennsylvania lime contains magnesia, and yet celebrated as is the Philadelphia mortar for whiteness and durability, and as are the fine farms of Chester and Lancaster counties, which are enriched almost entirely by lime, there is a universal prejudice against magnesian limestones. But this cannot last; and now that the Tide-water canal is opened, the Susquehanna river lime must soon rival that from Thomaston in our southern ports; and the home-made lime must here come into extensive use, though prejudice and a want of enterprise may long keep it unused and unknown. This rock belongs to the same formation, and precisely resembles much of that which I have seen in the western part of New Jersey. Its composition is no doubt the same, and this is seen in Professor Rogers's Geological Report of that State, to vary as to the proportion of carbonate of lime from seventy-five to eighty-eight per cent., the residue being chiefly silica, with a very small amount of carbonate of magnesia, iron and alumina. This too corresponds with the analysis given above of the limestone from Jones county, North Carolina. The silica is the least injurious ingredient, its principal effect being, unless the rock is burned at too intense a heat, merely to render less sand necessary in tempering it for mortar, while the magnesia is not only of small quantity but doubtful tendency, and the oxide of iron is generally in too minute proportion to seriously injure the lime by giving it a very dark color.

Besides the lime that will hereafter add to the mineral wealth of this region, there is near Pocataligo, on navigable tide water, a deposite of the purest quality of quartz sand, suitable for the manufacture of glass. The pebbles of which it consists are small, sharp, angular fragments of perfectly pure quartz, without any foreign mixture. It may be obtained in any quantity, and would probably pay for transportation as ballast under the cotton loads, either to the northern glass-houses or across the ocean. The locality is just half way between Charleston and Savannah, by the turnpike, on Mr. Spike's plantation.

There is one more locality of the secondary limestone I visited, which is near the Savannah river, in Georgia, at a place called Jacksonboro'. The perfect similarity of the rock with that in Jones county, North Carolina, and on the Santee and Edisto in South Carolina, admits of no doubt that it is the same with them, and continuous through this wide extent of country. Even to the straw color of the rock, the brooks flowing out at its base, the lukewarm water, and the little shells that inhabit it, they are all nearly alike. This has been partially quarried, and the limestone burned. On opening the bed it is found to be about twelve feet thick, and within from the surface, the stone is of a much whiter color, closely resembling chalk, and appearing as if it had already been burned. The heap of rock, in a hot southern sun, presents so dazzling an appearance that one's eyes and head seriously suffer from closely examining the pieces. They contain a great variety of fossil shells, affording most beautiful specimens; but I have not succeeded in obtaining those I collected. A rude kiln has been constructed of the coarse sandstone belonging to the same formation, and a considerable quantity of lime made. It

It is very white and good lime, such probably as the other localities described would afford, if worked as extensively. It is packed in boxes, which hold about three bushels, and these are sold along the river at the same price as a cask of Thomaston lime, *three dollars!* The locality is probably injudiciously selected, as it is eight miles from the river, up a little stream called Brier's creek, which is navigable for boats and rafts but a short time in the year, while the same bed might no doubt be found and opened on the river.

The inferior limestone at Shell Bluff belongs to a higher formation, and cannot be so important, though here too a great deal of cheap lime might be made from the rock and the fossil *Ostrea.* The specimens I collected at Shell Bluff, and on which I depended to describe the locality, having been lost, I will attempt no account of it, as it could now be only a repetition of what others have said. In one of the lowest fossiliferous bands at the bluff, I discovered a small jaw-bone of some land animal, which has not before been noticed there.

Catalogue of Medial Tertiary Fossils found at the Natural Well, Duplin County, North Carolina. Those in italics are new; of those undetermined, only the generic name is given.

Amphidesma constricta.
Amphidesma.
Anomia ephippium.
Arca incile.
" transversa.
Astarte lyrata.
" lunulata.
Astarte.
Balanus ovularis.
Buccinum lunatum.
" *interruptum.*
" *multirugatum.*
" *obsoletum.*
Calyptrea costata.
Calyptrea.
Calyptrea.
Cancellaria lunata.
" perspectiva.
Cardita tridentata.
" *perplana.*
Carditamera arata.
Cassis Hodgii.
Cerithium Carolinensis.
" dislocatum.
" *unilineatum.*
Chama congregata.
Conus adversarius.
Corbula cuneata.
Crassatella undulata.
Crepidula fornicata.
Cypræa Carolinensis.
Cytherea Carolinensis.
" reporta.
Diplodonta Americana.
Dispotaa multilineata.
" *dumosa.*
Fasciolaria mutabilis.
" rhomboidea.
Fissurella.
Fulgur canaliculatus
" excavatus.
" perversus.

Fusus.
Gnathodon minor.
Infundibulum centralis.
Lucina Jamaicensis.
" *radians.*
" *trisulcata.*
Lunulites denticulata.
" *depressa.*
Mactra crassidens.
" congesta.
" *subparilis.*
Marginella.
Mitra Carolinensis.
Monodonta.
Mytilus incrassatus.
Natica canrena.
" duplicata.
" heros.
" *Caroliniana.*
" *percallosa.*
Oliva idonea.
" litterata.
" mutica.
Ostrea disparilis.
" sculpturata.
Ostrea.
Panopœa reflexa.
Pecten eboreus.
Pectunculus Carolinensis.
" *quinque-rugatus.*
" subovatus.
Pleurotoma Virginiana.
Plicatula marginata.
Serpula granifera.
Solen.
Tellina.
Turritella.
Venericardia granulata.
Venus cortinaria.
" Rileyi.

Catalogue of Medial Tertiary Fossils found at Wilmington, North Carolina.

Amphidesma æquale.
" subobliqua.
" *nuculoides.*
" *protexta.*
Arca lienosa.
" limula.
" transversa.
Astarte lunulata.
" lyrata.
Balanus.
Cardium sublineatum.
Cardita abbreviata.
Chama congregata.
Corbula cuneata.
Crassatella undulata.
Crepidula fornicata.
Cytherea reporta.
Cytherea.
Diplodonta Americana.
Fulgur canaliculatus.
" carica.
" perversus.
Infundibulum.
Lucina anodonta.
" crenulata.
Lunulites.
Mactra congesta.
" lateralis.
Madrepora palmata.
Marginella.
Mytilus.
Nucula acuta.
" obliqua.
Oliva zonalis.
Orbicula lugubris.
Ostrea sculpturata.
" subfalcata.
Ostrea.
Panopœa reflexa.
Pecten eboreus.
Pecten.
Pectunculus Carolinensis.
" aratus.
Scutella.
Solecurtus Caribœus.
Solen.
Tellina.
Venericardia granulata.
Venus alveata.
" cortinaria.
" mercenaria.
" Rileyi.

Appendix to Mr. Hodge's Paper, describing the New Shells, &c.

BY T. A. CONRAD.

Mr. Hodge having requested me to name the fossils collected in his late excursion through a portion of the tertiary region, and to describe such as are new, I offer the following descriptions, and references to species formerly described; the localities visited by Mr. Hodge belong chiefly to the medial tertiary deposits; the other formations are the cretaceous and lower tertiary. One of the tertiary localities I noticed in Silliman's Journal, volume xxxix, p. 387, and described some of the shells which occur there, from specimens in the collection of my friend D. B. Smith. The following list of species is made out from his collection. The fossils are embedded in quartzose sand, with a large admixture of comminuted shells:

Natica canrena, Conus adversarius, Mitra Carolinensis, Fulgur excavatus, F. contrarius, F. maximus, Cyprea Carolinensis, Crepidula fornicata, Turritella Mitchelli, Cerithium Carolinensis, Buccinum multirugatum, Fasciolaria rhomboidea, Lucina Jamaicensis, Arca transversa, Mactra crassidens, Pectunculus quinquerugatus.

References and Descriptions of new Species.

OLIVA.

Oliva litterata, Lam. Plate V, fig. 1.

BUCCINUM.

Buccinum interruptum. Plate V, fig. 2. Elevated, subfusiform, with longitudinal ribs and transverse impressed lines, two below the suture; middle of the whirls entire, sides flattened, lower half of body whirl with equal prominent lines.

B. multirugatum. Ovato-conical, with numerous wrinkled spiral lines, coarser and more distant near the suture and at base of the body whirl; base bicarinated and subumbilicated; columella with a thick fold at base. Length two inches; width, one and one eighth inches: from the collection of D. B. Smith. Locality, Natural well, Duplin county, North Carolina.

CONUS.

Conus adversarius. Plate V, fig. 3. For description, see Silliman's Journal, volume xxxix, p. 388. Mr. Hodge has one dextral shell, the only one I have seen among eight or ten specimens of the species.

CERITHIUM.

Cerithium unilineatum. Plate V, fig. 4. Slightly turreted; volutions with each a spiral impressed line above the middle; space between this line and the suture with oblique plicæ.

C. Carolinensis. Subulate; whirls with impressed spiral lines and numerous acute longitudinal ribs, which are dislocated by a sulcus below the suture. Length two and a quarter inches. Resembles *C. dislocatum*, but is far larger, and has much more numerous and less prominent ribs.

MITRA.

Mitra Carolinensis. Plate V, fig. 5. For description, see Silliman's Journal, volume xxxix, p. 387, where it is inadvertently described as a *Voluta.*

CYPRÆA.

Cypræa Carolinensis. Plate V, fig. 6. Ovate, ventricose, superior margin of the labrum prominent at the apex; base plano-convex.

FASCIOLARIA.

Fasciolaria mutabilis. Plate V, fig. 7. For description, see Journal Acad. Nat. Sciences, volume vii. p. 135.

DISPOTŒA.

Dispotœa multilineata. Plate V, fig. 8. Subovate, depressed; apex prominent: one side with squamose lines, the opposite with finer ramose lines destitute of scales; diaphragm contracted.

D. dumosa. Plate V, fig. 9. Elevated, with ramose radiating lines and obsolete ribs, and with erect tubular spines; apex minutely spiral.

CASSIS.

Cassis Hodgii. Plate V, fig. 10. Elliptical, with numerous spiral lines, most prominent towards the base; spire conical, volutions convex.

PECTUNCULUS.

Pectunculus quinquerugatus. Lentiform, with very fine, crowded longitudinal striæ, and convex, slightly raised ribs; behind the umbo are five or six recurved plicæ or undulations. Length, three and three eighths inches.

P. Carolinensis. Lentiform, thick, posteriorly subcuneiform; ribs obsolete, radiating striæ strongly marked, minutely granulated; cardinal plate broad and thick; teeth obsolete; inner margin with numerous crenulations. Length, one and three eighths inches.

P. aratus. Obovate, with about twenty-eight ribs, about as wide as the intervening spaces, crossed by wrinkled lines; posterior margin obliquely truncated above the extremity, which is angulated; margin with about fifteen wide crenulations. Closely allied to *P. pectinatus.*

MACTRA.

Mactra crassidens. Plate V, fig. 11. Triangular, thick, convex-depressed; umboidal slope submarginal, angulated: beaks central; cardinal plate thick, lateral teeth robust. This species is from Mr. Smith's collection. It belongs to the genus *Mulinia* of Gray.

M. subparilis. Plate V, fig. 12. Triangular, elongated, moderately thick, convex-depressed: posterior side cuneiform; apex hardly oblique, subcentral; fosset wide; lateral teeth transversely striated. Belongs to the genus *Spisula,* Gray.

LUCINA.

Lucina trisulcata. Obovate, convex; with concentric lines, and two or three distant concentric furrows; lunule profound. Differs from *L. alveata* of the lower tertiary, in being less ventricose, and in the much more profoundly impressed lunule; the cardinal teeth are also very different.

L. radians. Orbicular, convex, with minutely waved or rugose concentric striæ, and radiating striæ obsolete on the middle of the valves, and most distinct on the anterior side; posterior submargin destitute of radiating lines; beaks central, prominent; margin crenulated. This species is recent at Mobile Point, Alabama, and occurs near Newbern, North Carolina.

MYTILUS.

Mytilus incrassatus. Thick, much inflated; anterior margin slightly incurved near the middle; basal margin not obtusely rounded; hinge thick, with slightly prominent, robust teeth. Length about three inches.

CARDIUM.

Cardium sublineatum. Plate V, fig. 13. Obliquely obovate, thin, slightly ventricose, with obsolete radiating lines, most distinct near the ends; submargins of anterior and posterior sides destitute of radiating lines; within striated: margin crenulated.

GNATHODON.

Gnathodon minor. Plate V, fig. 14. Trigonal, convex-depressed; posterior margin truncated and nearly direct. This makes the fourth species of this interesting genus, two recent and two fossil.

AMPHIDESMA.

Amphidesma constricta. Plate V, fig. 15. Oblong oval, ventricose; basal margin opposite the apex slightly contracted; end margins rounded; beaks nearest the posterior extremity; fosset profound; cardinal teeth prominent, lateral teeth none.

A. protexta. Oblongo-elliptical, compressed, with minute raised puncta; basal margin straight; apex prominent, about one fourth the length of the valve from the posterior extremity; posterior side slightly reflected; lateral teeth none. Length, seven eighths inch.

A. nuculoides. Ovate, convex, with very regular, minute concentric lines; anterior extremity acutely rounded; beaks near the posterior extremity; basal margin arcuate; lateral teeth obsolete.

CARDITA.

Cardita perplana. Plate V, fig. 16. Trigonal, nearly flat; ribs about eleven, angular, minutely granulated.

C. abbreviata. Plate V, fig. 17. Trigonal, elevated, convex-depressed, ribs about eleven, convex, minutely granulated; posterior extremity angulated. This and the preceding species belong to the genus *Venericardia* of Lam.

NATICA.

Natica Caroliniana. Plate V, fig. 18. Obliquely suboval, with obsolete spiral lines; umbilicus large, with a central rounded, prominent, thick carina; apex prominent.

N. percallosa. Spire convex-depressed; surface with fine, obsolete spiral striæ, umbilicus closed by a profound callus. Differs from *N. duplicata* in having the umbilicus perfectly concealed, and in the depressed spire. I think this species occurs recent on the southern coast.

INFUNDIBULUM.

Infundibulum centralis. Obtusely ovate, with fine concentric irregular lines; apex central.

POLYPARIA.

LUNULITES.

Lunulites denticulata. Prominently convex; apex slightly prominent; pores elliptical, arranged in quincunx order, and having slender projecting spines on the inner submargin; base with ramose, minutely granulated lines; margin denticulated.

L. depressa. Suboval, convex-depressed; pores unequal in size and irregular in form; many of the larger pores filled with a minutely porous plate or diaphragm, solid in the centre; others denticulated on the inner submargin; base granulated, and with very numerous minute ramose striæ, slightly impressed; margin denticulated.

A Sketch of the Infusoria, of the Family Bacillaria, with some Account of the most interesting Species which have been found in a recent or fossil State in the United States. By J. W. Bailey.

Those organized beings which Ehrenberg has placed among the Infusoria, in the family Bacillaria, present almost equal claims on the attention of the zoologist, botanist, and geologist. Containing, as this family does, those obscure organic bodies which form, as it were, the connecting links between the animal and vegetable kingdoms, and which appear to possess characters belonging to both, the student of either zoology or botany must examine them, and in fact the very simplicity of their structure renders them peculiarly proper for the observation of many phenomena of great physiological interest.

The geologist must attend to them, for the discoveries of Kutzing, Fischer, and especially of Ehrenberg, have shown that many of these minute bodies possess siliceous coverings, which occur in vast abundance in the fossil state, and which form the minutest, and yet not the least important nor least interesting, of the series of "nature's medallions."

Believing that some account of the structure, classification, &c., of this family would be acceptable to many in this country, and that figures of our most remarkable species would be of interest to the students of this family, both in this country and in Europe, I have devoted for some time past the very few leisure hours at my command, to the preparation of the following sketch. As an apology for the very imperfect state in which I now present it, I must state that my knowledge of the labors of others is necessarily very slight, as it is almost impossible to procure in this country any works relating to this branch of natural history. Of the many European works which contain figures of these obscure beings, scarcely one has been at my command, and as no one in this country has previously studied this subject, I have had to trust almost entirely to my own observations.

To avoid the risk of adding to the already burdensome synonymy, I have not attached any names to the species which I believed new, or which I could not determine satisfactorily, and shall merely refer to them by the numbers given to the figures representing them. I hope that these figures will enable some of the learned students of this family in Europe to decide which species are new; and perhaps if this paper should meet the eyes of Ehrenberg, he may oblige us by furnishing for publication the authentic names of the species I have represented in the accompanying plates.

For what relates to the classification and synonymy of this family, I am chiefly indebted to an abstract of Ehrenberg's work on Infusoria, which is appended to Mandle's *Traité pratique du Microscope. The generic and specific characters which I give are in most cases literal translations from this work.* I have also studied with much profit Kutzing's *Synopsis Diatomearum* in the *Linnæa* for 1833. The plates accompanying Kutzing's memoir have decided many doubts for me. Ehrenberg's great work on Infusoria I have not yet seen.

Without further preface, I shall now present a translation of Ehrenberg's characters for the

Family BACILLARIA.

" Polygastric (distinctly or probably*) without intestinal canal; appendices (distinctly or probably) variable, undivided, body multiform; carapace often prismatic and siliceous, with one or several openings, often having the form of articulated polypidoms, in consequence of imperfect, spontaneous (longitudinal) division." Ehrenberg divides this family into the following groups, namely:

Desmidiacea, having the carapace simple, free, and univalve, (not usually siliceous.)

Naviculacea, with the carapace simple, free, with two or more valves, (siliceous.)

* The question as to the correctness of Ehrenberg's views with regard to the internal structure of his Polygastrica, appears still undecided.

Echinellea, with the carapace simple, fixed, (siliceous.)

Lacernata, with the carapace double, (siliceous, and enveloped in tubes or gelatine.)

He separates the Closteria as a distinct family, but this genus is so closely allied to Euastrum, that I cannot hesitate to follow the example of most writers upon this subject, and to class them with the Desmidiaceæ.

The following analytical table of the genera of Bacillaria, is translated from Ehrenberg.

A. Carapace simple.	
A. Free.	
a. Univalve, ... *Desmidiacea.*	
a. Prismatic.	
1. Trilateral,	Desmidium.*
2. Quadrilateral,	Staurastrum.*
3. Pentagonal,	Pentasterias.*
b. Round.	
1. Smooth.	
aa. Polypidoms moniliform,	Tessararthra.
bb. " bacciform,	Sphærastrum.
2. With projections,	Xanthidium.*
c. Flattened.	
1. In forms of bands.	
aa. Serrated,	Arthrodesmus.*
bb. Not serrated,	Odontella.*
2. In form of discs or plates.	
aa. Several in each disc,	Micrasterias.*
bb. Two in each disc,	Euastrum.*
cc. Isolated in plates,	Microtheca.
b. Two or more valves, . . *Naviculacea.*	
a. Round.	
1. Globular,	Pyxidicula.*
2. Forming polypidoms.	
aa. One cell, chain filiform,	Gallionella.*
bb. Several concentric cells,	Actinocyclus.*
b. Prismatic.	
1. Division perfect, never forming bands.	
aa. With six (?) openings,	Navicula.*
bb. With four openings,	Eunotia.*
cc. With one opening,	Cocconeis.
2. Division imperfect, forming bands.	
aa. Articulated.	
aa. Prisms ("baguettes"),	Bacillaria.*
bb. Plates,	Tessella.*

bb. Without articulations.	
aa. Straight ribands, ...	Fragillaria.*
bb. Spiral ribands, ...	Meridion.*
B. Fixed, ... *Echinellea,*	
a. Wider than long, ...	Isthmia.
b. Longer than wide.	
a. Without a pedicel.	
1. Prismatic, ...	Synedra.*
2. Wedgeform, ...	Podosphenia.*
b. Supported by a pedicel.	
1. Wedgeform.	
aa. Dichotomous, ...	Gomphonema.*
bb. Verticillate, ...	Echinella.*
2. Fixed perpendicularly, ...	Cocconema.*
3. Fixed obliquely.	
aa. Opening in the middle, ...	Achnanthes.*
bb. Without opening in the middle, . . .	Striatella.*
B. Carapace Double, ... *Lacernata.*	
A. Surrounded by an amorphous gelatinous mass.	
a. Scattered, ...	Frustulia.
b. Joined in rings, ...	Syncyclia.
B. Surrounded by membranous tubes.	
a. Tubes separate.	
a. Frustules straight, ...	Naunema.*
b. " curved, ...	Gloenema.
b. Tubes joined.	
a. Fasciculate, ...	Schizonema.*
b. Branching, ...	Micromega.

The genera marked thus (*) have been detected in the United States.

Ehrenberg remarks of this family, that "the organization is difficult to recognize, in consequence of the hardness and refraction of the carapace. None have yet been found with calcareous coverings, but they are either hard and siliceous, (sometimes containing a little iron,) or membranaceous without silica. The differences observed in the forms of the carapace have been made use of in classifying them, (see preceding table.) In several genera, are found internal hyaline vesicles of variable form; these are colorless, and resemble the stomachs of the Polygastrica, and in recent experiments they have been colored by means of indigo. The female organs are colored or colorless granules, forming two or four groups, which are placed near the middle of the body, as in Navicula, Cocconema, Naunema, &c. These eggs are frequently divided into several globular groups, which finally unite in a cruciform manner, (Achnanthes) or which become confounded together, before being emitted, (Gallionella, Pyxidicula, Isthmia, &c.;) at other times they appear under the form of a tube enveloping the stomachs and other organs, (Xanthidium, Euastrum, Micrasterias.) The genera Micrasterias, Arthrodesmus, Tessararthra and Xanthidium, have organs which may be compared to seminal vesicles. Spontaneous division produces much variety in the forms of the polypidoms. It sometimes takes place longitudinally, sometimes transversely."

The living species of this family may be found in almost every situation where water occurs upon the surface of the earth. Some genera are exclusively marine, others are exclusively fluviatile, while some genera, as Navicula, Gomphonema, &c., include both salt and fresh water species. The marine species may often be found in great quantities among the filiform Algæ, which they often invest completely with their crystalline carapaces.

The fluviatile species may be found in every pond, stream, rivulet, bog, or pool, either nestling among Confervæ, parasitic on aquatic plants, or living in the sedimentary matter at the bottom. They often occur in such vast quantities as to cover hundreds of square yards, to which they give a peculiar color—green, yellowish or ferruginous, according to the peculiar internal coloring matter of the individuals. Most of the species are exceedingly minute, many are entirely invisible to the naked eye; others, however, are quite perceptible without the aid of the microscope. Notwithstanding their extreme minuteness, it is evident, from their vast abundance, that they have some important offices to perform in the economy of nature; and like the coral insect, although the individuals are minute, the result of their united labors is on a scale by no means insignificant.

Few organic bodies exceed in beauty the symmetrical, elegantly sculptured forms of many of the species. Their beauty, the singular phenomena they present, and the interest they have lately received from being detected in a fossil state in Europe and America, will be sufficient inducement for all lovers of microscopic research to study this family.

I shall now proceed to describe the most interesting American species, commencing with the

DESMIDIACEA.

DESMIDIUM.

Free, carapace simple, urceolate, trilateral, often catenate. Mandl. and Ehrenberg, l. c. p. 244.

1. *Desmidium Schwartzii. Ag.* (Pl. I, fig. 1.) "Corpuscles smooth, quadrangular on three sides, slightly emarginate, triangular on the other two sides, end obtuse, ovarium green, one ninety-second to one ninety-sixth of Paris line."

The corpuscles of this species are united together by their triangular faces, so as to produce long triangular (often twisted) filaments, which are of a beautiful green color, and exceedingly lubricous. Each filament is enveloped in a very transparent gelatinous matter, which is not visible on the dead specimens. The filaments often occur together in great quantities, and form a stratum in the water, which is not distinguishable from a mass of some species of Zygnema, with which remarkable genus of Algæ, this presents many points of resemblance. Allusion is made by several writers* to a "curious pinnatifid appearance" which this species presents "before the ultimate separation of the joints." I have not seen the filaments in this state, nor have I met with any detailed account of this change in the few works which I have been able to consult.

This species is extensively diffused in Europe, and appears to be equally so in this country. I have met with it from Rhode Island to Ouisconsin, and south to Virginia; it occurs at West Point in great abundance in ditches and peat bogs, where I have found it most abundant in early spring. I believe *Desmidium cylindricum* of Greville to be merely a *state* of this species.

2. *Desmidium hexaceros, Ehr.* (Compare figs. 2 and 3, Pl. I.) Corpuscles binary, trilateral, the points drawn out to three horns and truncate at the extremity, $\frac{1}{48}$ of line.

3. *Desmidium aculeatum, Ehr.* (Compare figs. 4, 5, and 6, Pl. I.)

* See *Agardh.* Systema Algarum, p. 15, and *Greville* in British Flora, vol. v. p. 402.

Corpuscles spiny, trilateral, the points drawn out to three truncate horns, often terminating in three spines.

I copy Ehrenberg's description of the two last species, that they may be compared with the figures referred to above, which represent various binary triangular bodies, some of which agree pretty well with the above characters. They however are so unlike D. *Schwartzii*, and present so many points of resemblance to Euastrum, that I shall describe them as species of that genus.

STAURASTRUM.

Free, a simple, univalve quadrangular carapace.

1. *Staurastrum paradoxum.* Corpuscles rough, single or binary, four setaceous horns in form of a cross.

Micrasterias Staurastrum, Micrasterias tetracera, didicera, tricera. Kutzing, Linnea, Vol. viii. p. 599, Pl. 20, figs. 83, 84, and 85.

St. paradoxum, Meyen, Nov. Act. Nat. Cur., xiv. p. 777, Pl. 43.

"Formed principally of two cells united end to end, and each terminated by cross-shaped prolongations, on which are perceived vestiges of articulation." See Ferussac's Bulletin, June, 1830.

I am not sure that I have yet met with this species in America; I have, however, often seen the binary bodies represented by figs. 3 and 4, Pl. I, having *four* arms instead of the three represented in our drawing. In the four-armed state they agree closely with the above characters of *S. paradoxum*, as well as with Kutzing's figure 83.

PENTASTERIAS.

Free, a simple univalve pentagonal carapace.

1. *Pentasterias margaritifera,* Surface granulated, rays thick and obtuse. Mandl. and Ehrenberg, l. c. Pl. 8, fig. 46.

I am unacquainted with this genus, unless it is founded on five-rayed bodies resembling figure 7, which are only varieties of figures 3 and 4, the number of arms being, as I have repeatedly seen, liable to much variation.

TESSARARTHRA.

Free, a simple carapace, univalve, globular, smooth, forming chains of four or more individuals by spontaneous division.

1. *Tessararthra moniliformis.* Corpuscles green, two or four united in a right line. M. and E. l. c. Pl. 8, fig. 47.

I have not noticed this genus in America.

SPHERASTRUM.

Free, a simple carapace, univalve, smooth, inflated, forming groups of various forms by imperfect spontaneous division.

I have not yet detected any specimens of this genus.

XANTHIDIUM.

Free, carapace simple, univalve, globular, bristling with points or setæ, isolated, binary or quaternary, (catenate?)

This genus is very interesting, from the fact that bodies, almost identical in form with the living species, occur abundantly, preserved in the fossil state in *flint*. Drawings of several fossil species may be seen in the Annals of Natural History, Pl. 9, accompanying an interesting paper on the Organic Remains in the Flint of Chalk, by the Rev. J. B. Reade. The directions given for finding these bodies in flint, are "to chip off thin fragments which may be attached by means of Canada balsam to slips of glass, and then coated on the outer surface with hard spirit varnish. A hundred specimens may be thus cut, polished, and mounted for the microscope without trouble and expense, and in less time than an expert lapidary could prepare a single slice with the diamond mill and polishing tool." Many of the common gun flints contain these bodies. I am indebted to E. J. Quekett, Esq. of London, for very fine specimens of fossil Xanthidia; among them is a slice of flint prepared by a lapidary, which contains in a space of less than a square inch, as many as eight or ten very perfect Xanthidia, a scale of a fish, and other organic bodies.

There has been much discussion as to the real nature of the bodies in flint which so closely resemble the recent Xanthidia. Turpin mistook them for eggs of Cristatella, to which however they have but little resemblance. Ehrenberg gives figures in his small treatise, "die Fossilen Infusorien und die lebendige Dammerde," Pl. I, figs. 2, 12 to 17, which show the closest resemblance between the recent and the fossil species. It is remarkable, however, that the recent species are inhabitants of fresh water, while flint is undoubtedly of marine origin. I have not seen distinct motion in any of our species.

1. *Xanthidium? ramosum.* Corpuscles globular, separate or binary, spines scattered, terminating in three or more points $\frac{1}{96}$ to $\frac{1}{24}$ line. Fossil in gun flints.

2. *Xanthidium* ———. (Fig. 15, Pl. I.) Binary, each portion having numerous rather long arms terminating in three diverging points.

This very beautiful American species is, when living, of a fine green color. Its carapace is hard and apparently siliceous, as it retains its form in spite of the action of fire and acids. Every living specimen of this species which I have seen, has been composed of two symmetrical portions, as shown in the figure. These bodies, when in the position shown in the figure, have much resemblance to Ehrenberg's drawings illustrating the spontaneous division of some of the species. When thrown into other positions, so that the line of union of the two portions is not seen, it may easily be mistaken for a *simple* spherical body bristling with arms. The two portions often separate after death, and may then be mistaken for individuals resulting from spontaneous division; but by throwing them into various positions by means of a compressor, the orifice corresponding to the line of separation of the two original parts may always be seen. The same remark will apply to the next species also.

It occurs not unfrequently in a subalpine pond a few miles from West Point; it is also occasionally found in ditches, in peat bogs, &c.

3. *Xanthidium* ———. (Fig. 16, *a*, *b*, Pl. I.) Binary, each portion somewhat triangular and terminating at each angle in three short, diverging arms, each having three small diverging points.

The smaller size and triangular form of these bodies, make me think them of a different species from the preceding. I have not seen any intermediate forms, although they occur together in about equal abundance at the above-mentioned locality.

I must here remark, that a transition from Xanthidium to Euastrum appears quite evident, through the binary triangular bodies, often having projecting arms, represented in figures 2, 3, 4, 9 and 8, Pl. I.

ARTHRODESMUS.

Free, carapace simple, univalve, compressed in the form of a plate, or a compressed band, articulated by spontaneous division.

1. *Arthrodesmus quadricaudatus.* (Fig. 17, Pl. I.) Corpuscles oblong, straight; chain or polypidom of four to eight individuals formed by imperfect spontaneous division, four horns, (the middle corpuscles rounded at the ends, the others with a horn at each end.) Size of corpuscles $\frac{1}{182}$ to $\frac{1}{96}$ line; chains $\frac{1}{48}$ line. *Scenedesmus magnus, Meyen.*

This species, as it occurs in this country, is composed of from four to eight green elliptical corpuscles arranged in a thread or chain, usually having horns only on the two extreme corpuscles, but not unfrequently similar projections may be seen on the middle ones also. Meyen, who considers this as a plant, states that in spring it contains starch globules.* It is extensively diffused, both in Europe and in this country; I have noticed it as far west as Ouisconsin, and south to Virginia. It is abundant in ponds near West Point, N. Y.

2. *Arthrodesmus cutus.* (Fig. 18, *a*, *b*, Pl. I.) Corpuscles green, oblong, alternating in a right line, by spontaneous division.

The small green bodies represented in our fig. 18, occur in the well at Fort Putnam, West Point. They appear to belong to this species.

ODONTELLA.

Free, carapace simple, univalve, compressed, form of flattened articulated ribands, often pierced, produced by imperfect spontaneous division, articulations united by small projections.

I have not *satisfactorily* determined any American species of this genus, although I have occasionally seen small filaments which agreed tolerably well with the generic character.

MICRASTERIAS.

Free, carapace simple, univalve, compressed, groups of a number of individuals in form of a flattened star, produced by imperfect spontaneous division.

* Meyen, Pflanzen Physiologie, Vol. III. p. 437.

This is a very beautiful genus, its species presenting elegant star-like arrangements of green corpuscles, some of which closely resemble in form the stars and badges of honor worn in Europe.

There appears to me to be much confusion in the specific characters, arising from the circumstance, that the *number* of corpuscles in the different rows has been made a character of specific importance. From what I have seen of the species, I am satisfied that the number of corpuscles in a star is liable to great variation in the same species. Perhaps the *form* of the corpuscles would prove a more certain character.

1. *Micrasterias Tetras.* (Fig. 19, Pl. I.) Four corpuscles united in form of star, the edge slightly notched.

This is a very minute species, which occurs in ponds near West Point. I have also noticed it in Virginia.

2. *Micrasterias Boryana.* (Fig. 20, Pl. I.) Ten corpuscles in the exterior circle, five in the interior, and one in the centre, edge acutely dentate. Corpuscles one eightieth to one hundredth of a line.

It happens *accidentally* that our figure represents an individual having just the number of corpuscles above described. I am satisfied, however, from frequent observation, that the *same species* sometimes has a much greater number of corpuscles, certainly *another row of fifteen* is often developed. It then agrees with M. *tricyclia* of Ehrenberg. It is a very beautiful object for the microscope. I have found it in New York, Virginia, and in Ouisconsin.

3. *Micrasterias* ———. (Fig. 21, Pl. I.) Corpuscles very numerous, forming large *imperforate* plates of a circular or elliptical form. Exterior corpuscles deeply emarginate, each having two projecting points.

This large and very beautiful species is not uncommon in ponds near West Point.

EUASTRUM.

Free, carapace simple, univalve, compressed, binary, sometimes quaternary, having the form of a two-lobed disc or lamina, often dentate.

The elegant forms and emerald green color of the species of this genus render them exceedingly fine objects for the microscope. The forms, as usually seen, appear tabular, but when thrown on their sides by means of a compressor, they show considerable thickness.

I have noticed in several species groups of molecules moving actively, precisely like those seen in Closterium. Indeed this genus is most closely allied to Closterium, and some forms occur which show a complete transition from one genus to the other. (See remarks under the head, *Closterium.*)

Capt. Carmichael, with his usual acuteness, detected their animal nature. He remarks of two of the species, "these are animals instead of plants, if the faculty of locomotion will entitle them to that rank." (See Hooker's British Flora, V. p. 398.) I have frequently noticed the motion of several species; it is quite as distinct in Closterium.

1. *Euastrum rota, Ehr.* (Fig. 22, Pl. I.) Body binary, lenticular, discoid, smooth, the edges dentate or spiny, one twenty-fourth to one tenth of a line. *Echinella rotata?* Greville.

The species represented in our figure appears to be the *E. rota* of Ehrenberg, and agrees pretty well with the account given by Greville of his *Echinella rotata*, which he describes as having the "frond plane, circular, divided by a line passing through the centre, each portion composed of radiating segments cleft nearly to the central line." (See Brit. Flora, V. p. 398.) Having seen no figures of the European species, I cannot be sure of their identity with ours.

The species represented in fig. 22, is quite common in the United States. I have seen it in Rhode Island, New York, Virginia, and Ouisconsin; I have generally found it scattered among Confervæ, but I once, in early spring, found *many hundreds* of them collected together on the bottom of a very small pool of water in a sphagnous bog. Some variety occurs in the outline; thus the two large central portions of each half are *often* perfectly symmetrical, and not unfrequently dentate near the ends. I have seen specimens twice the size of the one represented.

2. *Euastrum crux melitensis.* (Fig. 23? Pl. I.) Body binary, lenticular, discoid, smooth, the edges deeply divided into six dentate and spiny rays.

I copy this description, that it may be compared with fig. 23, Pl. I, which represents a very beautiful form which I have found in various situations near West Point, and also at Staten Island. I have seen it move distinctly.

3. *Euastrum* ———. (Fig. 24, Pl. I.) This is possibly only a younger state of *E. rota*, (fig. 22,) with which it occurs.

4. *Euastrum* ———. (Fig 25, Pl. I.) This very elegant form is somewhat rare. It occurs at West Point with the preceding.

5. *Euastrum* ———. (Fig. 26 and fig. 27, *a*, *b*, *c*, and *d*, Pl. I.) I suspect that the species represented in figs. 26 and 27, is the same as the *Echinella oblonga* of Greville, which he describes as being "compressed, oblong crenato-pinnatifid, and lobed, divided transversely almost to the centre." (Brit. Flora. Vol. V. p. 398.)

Fig. 27, *a* and *b* show two positions of the same individual; *c* and *d* show small individuals, which are probably the young of this species. Fig. 26, although much more deeply lobed than fig. 27, is *probably* only an older state of the same. They occur at West Point, also near Detroit, Michigan, and in Ouisconsin.

6. *Euastrum* ———. (Fig. 28, *a*, *b*, Pl. I.) This species is neither lobed nor undulate; but while the general outline is convex, a minutely serrated edge may be seen. When thrown on its side, (fig. 28, *b*,) it presents an unusual thickness.

If this species is compared with fig. 38, Pl. I, the close relation existing between the genera *Closterium* and *Euastrum* will be manifest.

7. *Euastrum* ———. (Fig. 29, Pl. I.) I suspect that the bodies represented in fig. 29, belong to this genus. They consist usually of four somewhat elliptical green bodies placed parallel to each other, and united laterally, as seen in the figure. Each elliptical portion is bidentate at the ends. I have met with specimens in which eight such corpuscles were united, producing such an appearance as would be given if a figure, like that shown in fig. 29, had a similar one added immediately below it.

If this is a species of Euastrum, perhaps it may be thus characterized; Euastrum ———. Fig. 29. Binary (or sometimes quaternary,) each corpuscle divided by deep lateral sinuses into two transverse, somewhat elliptical bidentate, portions, the middle portions longest. Occurs in ponds near West Point.

8. *Euastrum margaritiferum, Ehr.* (Fig. 8, *a*, *b*, Pl. I.) Body binary, elliptical, each part semi-orbicular with the margin entire, $\frac{1}{120}$ to one twenty-fourth of a line. *Heterocarpella tetropthalma, Ktz.* Linn. 1833, Pl. 19, fig. 87.

Our species (fig. 8,) agrees pretty well with the above description and with Kutzing's figure. A figure given by Meyen in his Pflanzen Physiologie, Vol. III. Pl. 10, fig. 31, apparently belongs to this species also.

The surface has a great number of minute, hemispherical projections, disposed in a quincuncial order. It is possible that the pearl-like appearance of these projections, when seen on the empty carapace, may have suggested the specific name. I have seen this species move quite distinctly, and have also seen in it (as well as other species of Euastrum) groups of moving molecules, as in Closterium; sometimes indeed the whole cavity is filled with such particles. Meyen states that the species he represents (l. c. fig. 31, Pl. 10,) contains globules of starch.

This species is very common in the neighborhood of West Point. I once found, in the spring of the year, in a small pool caused by the melting of snow in a peat meadow, a large cloud-like mass in the water, which, when touched, broke to pieces and became diffused through the water. On examination, it proved to be wholly made up of this species. I have found it in Rhode Island, New York, Ouisconsin, and Virginia.

9. *Euastrum* ———. (Fig. 9, Pl. I.) Binary, triangular, angles rounded, each corpuscle having several rows of minute points. Hab. West Point.

10. *Euastrum* ———. (Fig. 10, Pl. I.) Binary, elliptical, each corpuscle having three pairs of long subulate spines. Hab. West Point. I have met with individuals having the spines developed on only one side.

11. *Euastrum* ———. (Fig. 13, Pl. I.) Binary, corpuscles cordate at base, each having six pairs of short spines.

This is a very pretty species which occurs at West Point. The figure shows the position of two groups of active molecules.

12. *Euastrum* ———. (Figs. 11 and 12, Pl. I.) Binary, each corpuscle elliptical and terminating at each extremity in a single spine. Hab. West Point.

13. *Euastrum* ———. (Figs. 2, 3, 4, 5, 6, and 7, Pl. I.) Binary, (sometimes quaternary,) generally triangular, and terminating in three long arms, each of which ends in three minute spines. Hab. West Point.

The number of arms is *usually* three, but I have met with specimens in which one corpuscle had *three* and the other *four* arms, others in which *both* had *four*, and others again in which *both* had *five* arms.

It appears to me that the five-armed variety may have given rise to the genus Pentasterias, (page 118,) and the four-armed ones are possibly the same as Staurastrum, (page 118.) This however is only a conjecture, hazarded without having seen authentic specimens or good figures of those genera. The structure of the arms is exactly as in the Xanthidium, (fig. 15, Pl. I,) and there is indeed an evident relation between the genera.

The reader is requested to compare some of the figures last referred to, with the descriptions of *Desmidium hexaceros* and *D. aculeatum*, page 117.

14. *Euastrum* ———. (Fig. 14, Pl. I.) Binary, corpuscles triangular, each angle terminating in a sharp spine. Hab. West Point.

I have seen several other species of *Euastrum*, but the number figured is sufficient to give an idea of the variety and beauty of the forms in this interesting genus.

CLOSTERIUM. (*See Figs.* 30 *to* 38, *Pl. I.*)

Ehrenberg makes of this genus a distinct family of INFUSORIA, which he calls the *Closterina*, and characterizes thus:

"*Polygastric* (*distinctly or probably*) *without alimentary canal, without appendices, polypidoms having the form of a wand,* ("*baguette*,") *thread or spindle, by spontaneous division, papillæ fixed and movable in the opening of the carapace.*"

I have before stated that I consider the genus *Closterium* most closely related to *Euastrum*, and therefore with the *Desmidiacea* generally. This relation to *Euastrum* is manifest in their apparent identity in internal structure; the chief difference between them is only in the *external* forms, and even in them, we find there is a perfect transition from the highly lobed and tabular forms of some species of *Euastrum*, to the entire, elongated and fusiform species of *Closterium*. It is therefore without hesitation that I place *Closterium* (as indeed most writers do) among the *Desmidiacea*.

There has been much discussion of the question, whether the *Closteria* are plants or animals, and as this inquiry is one of general interest, the decision of which will affect the position of all the family Bacillaria, I may be excused for giving at some length, an account of the present state of the question. Ehrenberg gives the following reasons for believing the *Closteria* to be *animals*. 1. Their voluntary motion. 2. Their terminal openings. 3. The incessantly moving organs placed against the openings and sometimes projecting. 4. Their spontaneous lateral division.

Morren, in his celebrated memoir "*Sur les Closteriées*," (some notice of which may be found in Silliman's Journal, Vol. xxxv. p. 122,) supports the view that the *Closteria* are *plants*.

Meyen, in his report on Vegetable Physiology, for 1837, (p. 54, Francis' translation,) and also in his Pflanzen Physiologie, Vol. III. p. 437, has brought forward the fact of the presence of *starch*, in the *Closteria*, as conclusive evidence of their being *plants*. He states that the large and small globules in these bodies "at certain times, and particularly in spring, are almost wholly composed of starch." He adds that in the month of May he had observed "many specimens of *Closterium*, in which the whole interior substance was granulated, and all the grains gave with iodine a beautiful blue color, as is the case with starch, which is not an animal product."

In the Annals of Natural History for August, 1840, (No. 33, p. 415,) is given a notice of a paper read by Mr. Dalrymple before the Microscopical Society of London. As this paper gives a good idea of the present state of the discussion concerning the nature of the *Closteria*, I believe that no apology is necessary for taking from it the following extract, especially as my own observations enable me to confirm some of the statements and to correct others.

"The author, after detailing the history of *Closterium*, from its discovery by Corte in 1774, down to the present time, entered into a detail of its appearance and general structure; he described it as consisting of a green gelatinous and granular body, invested by a highly elastic and contractile membrane, which is attached by variable points to a hard siliceous shell, which was afterwards stated by Mr. C. Varley to resist even the action of boiling nitric acid. The form of *Closterium* is spindle-shaped or crescentic — the shell consisting of two horns, tapering off more or less to the extremities, and united at the central transverse line, constituting a perfectly symmetrical exterior. At the extremity of each horn is an opening in the shell, which, however, is closed within by the membranous envelope, wanting however in some specimens. Within the shell and at the extremity of the green body, is a transparent chamber containing a variable number of active molecules, measuring from the twenty-thousandth to the forty-thousandth of an inch; these molecules or transparent spheroids, occasionally escape from this chamber, and circulate vaguely and irregularly between the periphery of the gelatinous body and the shell; further, the parietes of this chamber have a contractile power. The author denied the existence of any papillæ or proboscides at this part, as well as the supposition of Ehrenberg that these moving molecules constitute the basis of such papillæ. He also denied the statement of the same distinguished observer, that if coloring matter was mixed with the water in which the *Closterium* resides, any motion was communicated to the particles of such coloring matter by the supposed papillæ, or by the active molecules within the terminal cells. A circulation of the fluids within the shell was observed, independent of the vague movements of the active molecules; this was regular, passing in two opposite currents, one along the side of the shell, and the other along the periphery of the gelatinous body. When the shell and body of the *Closterium* were broken by pressure, the green gelatinous matter was forcibly ejected by the contraction of the membranous envelope.

"The action of iodine upon the specimens was very remarkable; 1st, it did not, as reported by Meyen, stain the green body violet or purple, but orange-brown; 2d, it produced violent contraction of the investing membrane of the body, whereby the green matter was often forcibly expelled from the shell at the transverse division; it instantly annihilated the motion of the molecules in the terminal sacs, and the sacs themselves became so distended with fluid as to burst and allow the molecules to escape.

"The mode of reproduction was stated to take place, 1st, by spontaneous division; 2d, by ova; 3d, by interbudding, or the conjugation of two *Closteria*.

"The author, after balancing the arguments of the two theories respecting the classification of this body, gave as his reasons for retaining them on the side of the animal kingdom, the following summary:

"1st. That while *Closterium* has a circulation of molecules greatly resembling that of plants, it has also a definite organ, unknown in the vegetable world, in which the active molecules appear to enjoy an independent motion, and the parietes of which appear capable of contracting upon its contents.

"2d. That the green gelatinous body is contained in a membranous envelope, which, while it is elastic, contracts also upon the action of certain reägents, whose effects cannot be considered purely chemical.

"3d. The comparison of the supposed ova with cytoblasts and cells of plants, precludes the possibility of our considering them as the latter, while the appearance of a vitelline nucleus, transparent but molecular fluid, a chorion or shell, determines them as animal ova. It was shown to be impossible that these eggs had been deposited in the empty shell by other infusoria, or that they were the produce of some entozoon.

"4th. That while it was impossible to determine whether the vague motions of *Closterium* were voluntary or not, yet the idea the author had formed of a suctorial apparatus, forbade his classing them with plants.

"Lastly, in no instance had the action of iodine produced its ordinary effects upon starch or vegetable matter, by coloring it violet or blue, although Meyen asserts it did in his trials.

"The author therefore concluded that *Closterium* must still be retained as an infusory animal, although it is more than doubtful whether it ought to rank with the polygastric families."

Upon these statements of Mr. Dalrymple, I venture to offer the following remarks.

1st. *As to the siliceous nature of the carapace:* Ehrenberg expressly states, (l. c. p. 446,) that "the carapace can be burned and completely volatilized." This statement of Ehrenberg, together with the undoubted *flexibility* of the covering of many of the *Closteria*, which I have often noticed as wholly unlike the *brittle* siliceous coverings of the Naviculæ, and the fact that I have never found their coverings among the fossil Naviculæ, although the living species of each genus occur abundantly together, all induce me to think the carapace of *Closterium* can scarcely be siliceous.

2d. *Motions apparently voluntary.* — These are easily seen; I have often been unable to sketch the form of a specimen by means of the camera lucida, as the body was constantly changing its position, and this too when *certainly* undisturbed by the motion of other animalcules, or any extraneous cause. Their power of locomotion may also be rendered apparent thus: if a portion of mud, covered with *Closteria*, is placed in a glass of water, exposed to light, and the *Closteria* are then buried in the mud, they will soon work their way to the surface, covering it again with a green stratum, which may be buried over and over again, with the same results.

3d. *Presence of moving molecules in distinct cavities.* — These are easily seen; generally there is *one* such cavity in each extremity, as indicated in most of our figures of *Closterium*, (see figs. 30 to 38, Pl. I,) but sometimes there are *many* such cavities; at other times almost the whole interior appears filled with active molecules, as has already been stated (p. 123) is sometimes the case with *Euastrum.* In specimens where the cavities at the ends were very distinct, and which also showed very distinctly the circulation referred to by Mr. Dalrymple, I noticed that the form of the cavity containing the active molecules was constantly changing, being sometimes globular, then elongating to the left or right, and then becoming globular again, in a rapid but very irregular manner.

4th. *Presence of distinct circulation.* This was noticed many years ago by GRUTHUISEN. The account by Mr. Dalrymple, given in the above extract, agrees exactly with what I have seen in several species. The currents are very distinct, so much so, in fact, that they attracted my attention before I was aware that they had been noticed by others.

5th. *Action of Iodine.* — I cannot otherwise account for Mr. DALRYMPLE's statement that iodine "in no instance produced in the Closteria, the violet or blue color indicating starch," than by supposing that the specimens he examined were not in the proper state to exhibit it. MEYEN expressly states, that it is "at certain times, particularly in spring," that the starch may be detected.

I am able, by conclusive experiments, to *confirm* Meyen's statements as to the presence of starch in these bodies. In specimens gathered in November, many of which I have still by me in a living state, I find no difficulty in producing the blue or purple color with tincture of iodine. Sometimes, however, the specimen becomes so opaque by the action of this reägent, that the purple color of the granules can only be detected after crushing the specimen by means of the compressor. *The characteristic color of iodide of starch is then shown most distinctly.* I have repeatedly treated in this way the large species, *C. trabecula* (fig. 32, Pl. I,) as well as others, and have uniformly found that a portion of the interior takes the blue or purple color.

I cannot however consider the presence of starch in these bodies as conclusive evidence that they are plants. Is it not possible that they are animals which feed, wholly or in part, on amylaceous matter extracted from the aquatic plants among which they live? If so, the detection of starch in their stomachs is not surprising.

6th. *Organs of motion and moving papillæ.* — These I have not yet seen, but do not feel authorized to deny their existence, as I am well aware that my microscope,* although a very good one, is probably inferior to the one used by Ehrenberg. It shows the lines on the scales of Podura as well as I have been able to

* Made by Charles Chevalier, 130 Palais Royal, Paris.

see them by any instruments in this country, yet I have not sufficient confidence in its power, or my skill in using it, to contradict the statements of results obtained by so distinguished an observer as Ehrenberg, in using the best instruments of Europe. I can vouch very positively for what I have seen, but will not pretend that more may not be seen by others.

I will now proceed to describe briefly, some of the most interesting American species of Closterium, giving in connection with each the characters of the European species which *appears* to correspond to our own, as far as I can determine by the brief accounts, usually unaccompanied by figures, in the works to which I have access.

1. *Closterium lunula.* (Fig. 30, Pl. I.) Semilunar or straight, diminishing gradually towards the rounded extremities, internal glands scattered, green granules arranged in several (10) threads, one quarter to one twelfth of a line.

2. *Closterium moniliferum.* (Fig. 31, Pl. I.) Semilunar, never straight, smooth, acute, and rounded at the ends, internal glands in the middle of the body arranged in a moniliform manner, green granules in several rows, of which the three middle ones are most distinct.

Specimens agreeing with the characters of each of the above species are common in this country. They do not however appear to be specifically distinct. They may be easily recognized by their smooth, green, crescent-like forms.

3. *Closterium trabecula.* (Fig. 32? Pl. I.) Straight, cylindrical, contracted in the middle, smooth, the ends truncate, glands scattered or in several series, numerous obscure bands, one twelfth to one fifth of a line.

I have seen no figure of this European species, but I nevertheless venture to refer to it, the fine species represented in figure 32. This is the *largest* Closterium which I have seen in the United States. It occurs at West Point, at Staten Island, and in Virginia.

Its motions are quite distinct, the cavities containing moving particles very apparent, and what appear to be terminal openings may be easily seen. By application of tincture of iodine, and then crushing the specimen under the compressor, starch globules may easily be detected. In crushing, the globules are often forced out at the terminal openings, and on relieving the pressure are drawn back again. No rupture of a membrane at these points was perceived.

4. *Closterium digitus.* (Fig. 33 ? Pl. I.) Straight, oval, cylindrical, four or five times longer than broad, smooth, the ends very much rounded, sometimes showing traces of a spontaneous triple division, longitudinal bands often denticulate, one twentieth to one tenth of a line.

With this account may be compared fig. 33, Pl. I, which represents a species not uncommon at West Point, and which I have also seen in Rhode Island, Virginia, and Ouisconsin.

Its endochrome usually presents a central mass, from which several (10 ?) undulating ridges radiate to the carapace. It is a very elegant species.

5. *Closterium lineatum.* (Fig. 34 ? Pl. I.) Very long, acute, slightly arcuate, cylindrical, filiform in the middle, the ends truncate, and very attenuate, ("*très amincis,*") ridges distinct, in form of smooth lines. Often thirty times longer than broad, one eighteenth to one eighth of a line.

Compare with this fig. 34, Pl. I, which represents a species quite common in ponds near West Point, and which also occurs in Virginia. The figure represents only one half of the excessively elongated body. In the living specimens, the endochrome shows distinct ridges.

6. *Closterium striolatum.* (Fig. 35 ? Pl. I.) Fusiform and arcuate, ends acute and truncate, ridges smooth, not deep, ten or twelve times longer than broad, one tenth of a line.

Compare fig. 35, Pl. I, which represents a common species.

7. *Closterium rostratum, Ehr.* Fusiform, slender, ends acute, setaceous horns about as long as the body, sometimes shorter. *C. acus, Ktz.* Linn., 1833. fig. 81.

I suspect the species shown in fig. 36, Pl. I, is a young state of this species. I found it among Lemna minor, on Staten Island, New York. Fig. 36, *a*, shows an individual produced by spontaneous division, one portion of which is still imperfectly developed.

8. *Closterium tenue, Ktz.* "Corpusculis minutis lineari-lanceolatis, viridi hyalinis, transversè fasciatis, acutis." See Linnæa, 1833, Pl. 8, fig. 78.

I find no notice of this species in the extract from Ehrenberg's work, appended to Mandl's work on the microscope, but as Kutzing's fig. 78 resembles our species, (fig. 37, Pl. I,) I quote his description, that they may be compared.

Our species occurs in vast abundance on the muddy bottom of a brook which crosses the Canterbury road, a few miles from West Point. It forms a mass of such extent, and of so bright a green color, that I at first mistook it for a layer of Oscillatoria.

There are very fine transverse lines, often visible on the carapace, and it often appears as if a portion of the shell between these lines (as at *a*, *b*, fig. 37, pl. I,) had been removed. Its motions are distinct and lively.

9. *Closterium* ———. (Fig. 38, Pl. I.] Nearly cylindrical, contracted in the middle, ends obtuse, and in one position showing a re-entering fold of the carapace. Hab. ponds near West Point. A similar fold in the carapace is visible in some species of Euastrum. (See fig. 27, Pl. I.)

MICROTHECA.

Free, carapace simple, univalve, compressed, separate, lamelliform.

M. octoceros. Carapace quadrangular, hyaline, four spines at each end, internal body golden yellow.

I am unacquainted with this genus.

NAVICULACEA.

Having given in the preceding part of this memoir, some account of those Bacillariæ which belong to the section Desmidiacea, I continue the subject, by describing the Bacillariæ of the section Naviculacea.

As all the species referred to this section have siliceous coverings, they often occur in a fossil state, and hence their study is of peculiar interest to the geologist. In beauty of form and elegance of structure, they will bear comparison with almost any class of organized beings.

PYXIDICULA.

Free, carapace simple, bivalve (siliceous) separate, globular, (may be compared to a Gaillonella with perfect spontaneous division or without division.)

1. *Pyxidicula operculata.* (Pl. II, fig. 1 and 1 a.) Body spherical, divisible into two hemispheres, carapace hyaline, internal organs greenish yellow, $\frac{1}{120}$ to one forty-eighth of a line.

I have seen hemispheres, probably derived from this species, among fossil infusoria from Manchester, Mass., &c.

2. *Pyxidicula globata.* This name has been given to globular bodies found in flint. Beautiful figures of them by Bauer, will be found in Pritchard's Hist. Infusoria, pl. 12, figs, 506 to 509. It is now suspected that these bodies are the gemmules of sponges, as the ramified tubes of sponge are often found preserved in the same pieces of flint.

3. *Pyxidicula?* (Pl. II, fig. 2, a, b.) The spheroidal bodies, represented by these figures, occur in the tertiary infusorial stratum discovered by Prof. W. B. Rogers in Virginia. Of the real nature of these bodies I am quite uncertain; they agree however with Pyxidicula, in separating into two hemispherical portions. The surface is beautifully marked with rows of circular or hexagonal spots or cells, resembling those on the beautiful species of Coscinodiscus which accompany these bodies in the same deposit.

GAILLONELLA.

Free, carapace simple, bivalve (siliceous), form cylindrical, globular or discoid, producing chains [long articulated cylinders] by imperfect spontaneous division.

1. *Gaillonella moniliformis.* (Pl. II, fig. 3.) Corpuscles smooth, cylindrical, short, conical at the sides and truncate, form octangular [?] circular when seen endwise, ovaries green, one seventy-second of a line. *Ehr. Meloseria moniliformis, Ktz.*, Linn., 1833, Pl. 17, fig. 71. *M. nummuloides, Grev.*, in Brit. Flora, V. p. 401.

This very beautiful species grows only in salt or brackish water, and occurs in great abundance in various places in the United States. I first noticed it several years ago, among specimens of *Algæ* from Providence, R. I. I subsequently found it almost covering the bottom and shores of Providence Cove at low tide. I found it again in vast quantities, in salt ditches near the railroad at Stonington, Conn., where it formed large fleecy masses, sometimes of several feet in extent. Still more recently I have found it at Staten Island, and also, much to my surprise, sixty miles up the Hudson river, near West Point.*

The form is not strictly octangular, but at first appears so, in consequence of the two minute projections of the delicate transverse ridges seen near the ends of each of the two globules belonging to a joint. They do not change their form when heated to redness, nor by action of hot hydrochloric acid. They fuse with effervescence with carbonate of potassa, and the fused mass when treated with hydrochloric acid gives silica in abundance. There can, then, be no doubt that the glass-like filaments of this species are siliceous. Our species agrees in all respects with authentic European specimens (in Herb. Tor.) collected by Hoffman Bang, at Hoffmansgave.

2. *Gaillonella aurichalcea.* (Pl. II, fig. 4, 4 a?) Corpuscles elongated, cylindrical, truncate, flattened, smooth, contiguous, a simple or double pierced furrow in the middle of the body, ovaries greenish, becoming golden yellow when dry, $\frac{1}{192}$ of a line. *Conferva orichalcea Ag.*, Syst. Alg. p. 86. *Meloseira orichalcea, Ktz.*, Linn., 1833, p. 72, 588, Pl. 17, fig. 68.

Our species (Pl. II, fig. 4, a, b,) agrees so closely with Kutzing's figure 68, even in the branching character and occasional production of large globular joints, (see (c) in fig. 4,) that I feel little hesitation in considering it as the *G. aurichalcea*, although I am

* The Flora and Fauna of the Hudson River at West Point, would, in a fossil state, be rather puzzling to the geologist, on account of the singular mixture of *marine* and *fluviatile* species. While Vallisneria and Potamogeton grow in such vast quantities in many places as to prevent the passage of a boat, and the shore is covered with *fluviatile* shells, such as Planorbis, Physa, &c. in a living state; we yet find the above fresh-water plants entangled with bunches of marine Algæ, such as Enteromorpha, Ectocarpus, &c., and often covered with *marine* parasitic zoophytes and *marine* infusoria, (Achnanthes, Gaillonella, Echinella, Naunema, &c.; while the rocks below low water mark are covered with Balani and minute corallines, and the marine flora is represented by vast quantities of a very elegant Polysiphonia, (*P. subtilissima Mont.*?) abundance of Enteromorpha intestinalis, Ectocarpus siliculosus, and an elegant Alga, identical with Delesseria Leprieurii of Montagne, which was first detected on the shores of Cayenne. (See Annales des Sciences Naturelles, 2d series, Bot., tom. 13, p. 196, and pl. 5.)

unable to perceive the "sillon percé" alluded to by Ehrenberg in his specific character. This species might easily be mistaken for a Conferva. It often forms bluish green masses, of full a foot in extent, and while fresh it is quite as flexible as any Conferva; but on drying, it becomes of a light brassy yellow color, and is then excessively fragile. There is much variation in the diameter of the filaments, and in the relative length of the joints. The filaments which have the smallest diameter, have, generally, the longest joints. They retain their forms when heated to whiteness, and when treated with strong nitric acid. This species occurs in springs, rivulets, &c., and appears as common in this country as in Europe. In (Pl. II, fig. 4, b,) is represented a species of Gaillonella apparently distinct from figs. 4 and 4 a. It shows the pierced furrows, and agrees in most respects with the figure of *G. aurichalcea* given by Ehrenberg in his memoir entitled *Die Fossilen Infusorien und die lebendige Dammerde*, Pl. 1, fig. 23. It is, possibly, only a state of our species above referred to. It occurs in ponds near West Point.

3. *Gaillonella distans.* (Pl. II, fig. 5.) Corpuscles cylindrical, short, truncate and flattened on the ends, smooth, with two pierced furrows, always separated in the middle, $\frac{1}{576}$ to $\frac{1}{72}$ of a line, usually $\frac{1}{288}$.

This species occurs in vast quantities in the fossil state in Europe. It constitutes a large portion of the slate of Bilin and Cassel, and of the "Berghmehl" or "fossil farina" of various localities. It occurs in most of the specimens of American fossil infusoria, which I have seen. It is particularly abundant in the specimens from Manchester, Mass., which are chiefly composed of exceedingly minute frustules of this species. It forms here, a true fossil farina, almost as light as flour, and containing in a cubic inch many hundred millions of these minute siliceous shells. It occurs in a living state at West Point.

4. *Gaillonella varians.* (Pl. II, fig. 6, a, b.) Corpuscles flat on each end, cylindrical surface smooth, ends with fine radiating lines, ovaries yellow or green, $\frac{1}{192}$ to one fortieth of a line.

Our fig. 6, represents a species which is not uncommon in ponds near West Point. The discoid surfaces of the individuals show minute radiating lines quite distinctly.

5. *Gaillonella sulcata.* (Pl. II, fig. 7, a, b ?) I noticed fragments of this species two years ago in peat from a salt marsh near Stonington, and among marine Algæ in the same vicinity. I had prepared a sketch and description of it for this memoir, before I heard of the discovery of the infusorial stratum of Virginia. I was, therefore, agreeably surprised to find, on inspecting specimens of the fossil infusoria from Richmond, Rappahannock Cliff, &c., that this species was very abundant in them. A careful comparison of the recent specimens from Stonington, and the fossil specimens from the tertiary of Virginia, has left no doubt in my mind of their *specific identity.* The following is the account of the recent specimens, written several months before the reception of the Virginia fossils. They consist of frustules, each of which is divided by a transverse line; the *cylindrical* surface of each frustule has a great number of parallel lines in the direction of the axis, and the ends or *flat* surfaces show a rim having lines corresponding to those on the cylindrical surface; within this rim is a diaphragm having minute radiating lines. Chains of thirty or forty individuals are not unfrequent in the infusorial earth of Richmond, particularly in the upper part of the stratum. These are doubtless the "oblong cylinders" alluded to by Prof. W. B. Rogers in his Report on the Geological Survey of Virginia, p. 39. Ehrenberg gives the following description of *Gaillonella sulcata,* a fossil species occurring in the schist of Oran; from this description I suspect it to be closely allied to our species, and therefore copy its specific characters for the purpose of comparison.

" *Gaillonella sulcata.* Corpuscles cylindrical, short, truncate at the two ends and flattened, furrowed across and in form of cells" (sillonnés en travers et sous forme de cellules,) $\frac{1}{96}$ to one $\frac{1}{72}$ of a line.*

* In Pritchard's History of Infusoria, Recent and Fossil, I find a figure of *Gaillonella sulcata,* which leaves little doubt that our fossil specimens from Richmond, as well as our recent ones from Stonington, belong to this species. The living animals have also been detected at Cuxhaven, by Ehrenberg. See appendix to Pritchard's work, p. 434.

6. *Gaillonella?* ———. (Pl. II, fig. 8.) Corpuscles long, cylindrical, with two lines of constriction, adhering by alternate angles so as to form long zigzag chains, and occasionally auricled.

The curious bodies represented in Pl. II, fig. 8, appear to partake of the characters of both Gaillonella and Bacillaria, showing the cylindrical corpuscles of the former, united by alternate angles, as in many species of the latter. It is perhaps, related to *Diatoma auritum* of Lyngbye, which is described as having the "joints quadrangular, rounded, with an auricle at each angle," and of which Greville remarks that the auricular appendages of the angles give to the frustules the appearance of "microscopic woolpacks." Having seen no figure or specimen of *D. auritum*, I cannot decide as to its identity with our species; I believe, however, that ours must be different, both from its abundance and from the remark of Kutzing (Linnæa, 1833, p. 585) that *D. auritum* probably belongs to the Desmidiacea.

Our species consists of large cylindrical siliceous joints, usually adhering together by the alternate angles in a zigzag manner. Most of the frustules show two lines of constriction, as shown in the figure. The connection of the frustules is by a very conspicuous, flexible hinge-like ligament, which often gives to the joints an auricled appearance, and makes the comparison of them to "microscopic woolpacks," or rather bales of cotton, not inappropriate. The joints usually contain a yellow or ochraceous substance, arranged in a stellate manner, and not unfrequently this appears to be composed of minute globules, (ova ?) as shown in the figure. This species occurs, in vast quantities, in the Hudson River, at West Point. It may be found in some places at low tide, giving to the shores a ferruginous color in spaces even as much as a hundred square yards in extent.

7. *Gaillonella ferruginea.* Corpuscles very minute, convex on the ends, ferruginous, oval, smooth, having the form of articulated threads, often united, almost branching, $\frac{1}{3000}$ to $\frac{1}{1000}$ of a line.

Ehrenberg states with a mark of doubt, that it occurs in all ferruginous waters; fossil in bog iron ore; and in the yellow opal of Bilin. A copy of Ehrenberg's figure may be seen in

Lyell's Elements of Geology, p. 39, (Am. edit.) and in Pritchard's Hist. Inf. fig. 129–130. I have often seen in bogs and small streams, large quantities of a ferruginous colored flocculent matter, which dispersed with great ease when touched, and in which I have sometimes been able to see, by means of the microscope, excessively minute filaments, which were apparently moniliform. I believe these filaments to be the *G. ferruginea* of Ehrenberg, which is the same as the *Oscillatoria ochracea* of various algologists. The filaments are fragile and incombustible, and are said to be composed of silicate of iron. (See Pritchard's Hist. Inf. p. 199 and 200.)

ACTINOCYCLUS.

Free, carapace simple, bivalve, (siliceous) form cylindrical, (discoid) divided internally by several radiating partitions; spontaneous division imperfect, in form of a chain.

Ehrenberg mentions seven species, namely, A. ternarius, A. quaternarius, A. quinarius, A. senarius, A. septenarius, A. octonarius, and A. denarius, distinguished respectively by the number of cells formed by the radiating partitions. Several species occur in the "schiste of Oran" in Africa, in a formation which M. Rozet considered as tertiary, but which Ehrenberg suspects is more nearly connected with the chalk.

It appears to me to be an interesting fact, that the remarkable *marine* infusorial deposit discovered by Prof. W. B. Rogers in the tertiary formation of Virginia, appears to agree with the infusorial conglomerate of Oran, in containing several species of Actinocyclus, together with *Gaillonella sulcata*, and beautiful punctate discs, which I suspect belong to the genus Coscinodiscus. I have seen no account of this last genus, but its name appears peculiarly appropriate to the *sieve-like discs* which form so large a portion of the infusorial stratum of Richmond, Va. Ehrenberg mentions *Coscinodiscus patina* as predominating in the deposits of Oran, Zante, Caltasinetta, &c. (See Weaver's View of Ehrenberg's Observations in Lond. and Ed. Phil. Journ. for May, 1841, p. 393.) In Pl. II, figs. 9, 10, and 11, are represented several fossil species of Actinocyclus from Richmond; the same species also occur fossil in cliffs on the Rappahannock River. In figs. 12, 13, and 14, are represented the discs which I believe to belong to the genus Coscinodiscus. When perfect, the form seems to be that of a torus, having the circular bases covered with hexagonal or circular spots, which present considerable variety in their size and arrangement in different specimens. The most usual disposition of the spots is in rows corresponding with the radii, as shown in the large specimen, fig. 14. In consequence of this arrangement, they also form beautiful spiral rows in other directions, so that the curves present no inconsiderable resemblance to those often seen on the back of watches; at other times the spots are found to form three sets of lines, making angles of sixty degrees and one hundred and twenty degrees with each other, as shown in fig. 12, and on others the spots are disposed without much apparent regularity, frequently having a star-like figure in the centre. The spots are so small on some of the discs, as to be almost invisible even by the highest magnifying powers; on others, as in fig. 14, they are quite large and distinctly hexagonal. The largest discs have not always the largest spots. There are certainly several species of this genus in the infusorial stratum of Richmond, Va., but as I have not seen Ehrenberg's account of the European species, I cannot venture to name our own.

Note, *Oct.* 10*th*, 1841. — Since the above was ready for the press, I have seen in the appendix to Pritchard's History of Infusoria, living and fossil, some interesting statements of recent discoveries by Ehrenberg, with reference to the genera of Actinocyclus and Coscinodiscus. It appears that these genera, which were first discovered in a fossil state in the schists of Oran, Caltasinetta, Zante, &c., have also been recently found in sea water,* and that many of the living species are identical with the fossil ones; indeed, Ehrenberg states that *Actinocyclus senarius*, *Coscinodiscus patina*, and *Gaillonella sulcata*, species now living,

* Since the above note was written, I have found several species of Coscinodiscus and Actinocyclus, in the living state, quite abundant in the harbors of New York and Boston, and also in the Hudson River at West Point.

may be shown as the chief forms met with in the chalk marls of Sicily, and also that the species of the chalk formations are yet to be found, as crowds of living creatures in the waters of our seas.

I select from the species of Coscinodiscus, described by Ehrenberg, the following, as apparently identical with American species from Richmond, Va. In connection with the description, I give a reference to figures drawn by me from fossil American species, long before Ehrenberg's characters for the species were received.

Coscinodiscus lineatus. (Pl. II, fig. 12, a, b.) Carapace marked by small cells disposed in a series of parallel and transverse lines. Found fossil in the chalk marl of Caltasinetta, and in the live condition at Cuxhaven. The cells in this species form parallel lines in whatever direction they may be viewed. In large and well preserved fossil specimens, as many as twenty-five openings were seen near the circumference. Within the live forms, numerous yellow vesicles are sometimes seen, as in Gaillonella. Diameter of fossil, $\frac{1}{1150}$ to $\frac{1}{480}$; living, $\frac{1}{1150}$ to $\frac{1}{860}$. Fossil at Richmond, Virginia. Living in New-York harbor.

Coscinodiscus radiatus. (Pl. II, fig. 14.) Carapace large, marked with cells of moderate size, disposed in lines radiating from the centre. Towards the margin, the cells become smaller in size. Very abundant in the fossil state at Oran, alive near Wismar and Cuxhaven, $\frac{1}{860}$ to $\frac{1}{240}$ of a line. Fossil at Richmond, Va. Living in New-York harbor.

Coscinodiscus Argus, (? var. of *C. radiatus.*) Carapace with large cells at the centre, and smaller ones at the circumference, the order of the rays being often interrupted.

Fossil at Oran and Caltasinetta in chalk marl, living in sea water at Cuxhaven. The cells of the discs from Oran vary very much in size. The ova are of a greenish color in the living forms, which are very rare. Diam. $\frac{1}{860}$ to $\frac{1}{290}$ of a line. Fossil at Richmond, Virginia.

Coscinodiscus oculus-iridis. Carapace marked with rather large radiant cells, except near the centre and circumference, where they are smaller. Some of the larger cells in the centre form a sort of star. Fossil in the chalk marl of Greece; alive near Cuxhaven. Diameter, $\frac{1}{210}$. This large species is curiously marked, whilst under the microscope, with colored rings, which are apparently caused by the peculiar arrangement of the cells. There are generally from five to nine large cells at the centre. Specimens are found in the infusorial stratum of Richmond, Va., which have the star-like centre and probably belong to this species.

Coscinodiscus patina. (Pl. II, fig. 13, a. b.) Carapace large, cells of moderate size disposed in concentric circles. Cells smaller towards the circumference. Fossil in chalk marl of Zante, alive at Cuxhaven. The young and vigorous specimens of live individuals are completely filled with yellow granules, whilst the older ones have an irregular granulated mass within them. Diameter, $\frac{1}{860}$ to $\frac{1}{240}$ of a line. Fossil at Richmond, Va. Our figure shows a small specimen.

Of the genus Actinocyclus, Ehrenberg describes several new species, which have been found fossil in the chalk marls of Oran, Caltasinetta, &c., and living in sea water at Cuxhaven, Christiania and Tjörn. Several of these species have no partitions, but have surfaces marked with minutely punctate rays. The great variety which occurs among the forms of Actinocyclus, found fossil at Richmond, leave no doubt in my mind, that all of Ehrenberg's species will be found among them. I have also seen living species of this genus, and of Coscinodiscus, in the ooze of the Hudson River, near West Point.

For Ehrenberg's characters for the new species, see Pritchard's Hist. Inf., p. 428–429.

Navicula.

Free, separate or binary, carapace simple, bivalve or multivalve, (siliceous) having six [?] openings; never united in form of a chain by perfect spontaneous division.

On these characters as given by Ehrenberg for the genus Navicula, I would remark that there do not appear to be any true valves or parts capable of separation without fracture, although each species will usually break along certain lines or edges into a definite number of parts. I have not been able to satisfy myself of the existence of six openings in *N. viridis*, (see remarks concerning that species,) and with regard to the species ever forming chains, I can state that it is not rare to meet with four, sometimes even eight united laterally. I have even seen them thus united in the fossil state.

a. Having transverse striæ, (internal cells,) subgenus Surirella.

Navicula viridis. (Pl. II, fig. 16, a, b.) Striate, carapace straight, lateral faces truncate at the ends, ventral faces rounded at the ends, fifteen striæ, (cells) in $\frac{1}{100}$ of a line. Length, $\frac{1}{96}$ to one sixth of a line.

This beautiful species is one of the largest and most abundant, both in the recent and fossil state. It occurs all over Europe, and is equally diffused in this country. I have myself observed it in Maine, Massachusetts, New-York, Ouisconsin and Virginia. It is easily recognized by means of its large size and beautifully marked ventral faces. The striæ seen on these faces may *correspond* to internal cells, but I believe them to be linear openings in the carapace itself, as may easily be seen on the fragments of fossil specimens. There are three rounded spaces on each ventral face, which I think have been mistaken for openings, but which appear to me to be thicker portions of the carapace. One of these spaces is in the middle, and the other two at the extremities of the striated surfaces, and they are connected by a very delicate double line (canal?) A similar structure is seen on several other species of Navicula, Cocconema and Gomphonema. The real orifices are shown at *c*, *c*, *c*, *c*, in our fig. 16, *b*. Moving particles somewhat like those of Closterium may sometimes be seen near the extremities. In fig. 17, a, b, Pl. II, I have copied from Ehrenberg, (Die Fossilen Infusorien und die lebendige Dammerde, Berlin, 1837, Pl. 1, fig. 19,) a sketch in which he represents the organs of motion, the stomach, &c. of this species. The reference letters having been omitted by the engraver of Ehrenberg's plate, I have been obliged to insert them according to what I believe was their intended position.

The following is a translation of Ehrenberg's explanation of this figure. (See fig. 17, Pl. II.)

" A living specimen of *Navicula viridis* in which by the injection of indigo are distinctly to be seen, the stomach *v*, the two great spherical sexual glands *s s*, and the lamelliform extensions of the green ovarium, o′ mouth opening, o′ sexual opening? a, a, a, a, four movement openings, *p* the pediform organs of motion. The visible currents on the body, both when creeping and at rest, are denoted by arrows."

2. *Navicula viridula.* Carapace straight, lanceolate, linear, very slender, truncate at the ends, flattened on one side, lanceolate and obtuse on the other, thirteen to fifteen striæ in $\frac{1}{100}$ of a line, $\frac{1}{250}$ to $\frac{1}{24}$ of a line. *Frustulia viridula, Ktz.*, Linn. 1833, Pl. 13, fig. 12.

Ehrenberg mentions this as one of the species detected by him among fossil infusoria from West Point. Kutzing's figure does not allow me to determine with certainty, which of the various forms occurring at West Point, belongs to this species.

3. *Navicula* ———. (Pl. II, fig. 18.) This figure represents a panduriform species, very much contracted in the middle. It occurs in peat from a salt marsh near Stonington, Conn.

4. *Navicula* ———. (Pl. II, fig. 19.) This species occurs with the last, and is perhaps a state of it resulting from its complete spontaneous division into two individuals by the contraction at the middle.

5. *Navicula* ———. (Pl. II, fig. 20.) This resembles the preceding very much, but is a fresh-water species, occurring in ponds near West Point; also in streams in Virginia.

6. *Navicula? striatula.* (Pl. II, fig. 21, *a, b.*) I refer to this genus, with much hesitation, the very elegant and interesting species shown by fig. 21 *a, b.* It is easily known by a set of peculiar and beautiful undulating ridges, represented in the figure, and which give to the margin of the form a ruffled appearance, in whatever position they are observed. One of the faces (a) is lanceolate, the other (b) is somewhat wedgeform, with both ends obtusely truncate. The lanceolate face shows a set of fine lines apparently proceeding from the ridges above referred to, and reaching nearly to the middle line of the face. I have sometimes seen two individuals united laterally by their lanceolate faces, producing a very beautiful form. All the individuals which I have seen, have been free, without pedicel, and when living, their spontaneous motions were very distinct. I have found it in a living state in fresh-water ponds and streams near West Point, also in Mountain Run, near Culpepper Court House, in

Virginia; and I detected it in a fossil state among other fossil infusoria from Bridgewater, Mass. (See figs. 6 and 7, pl. 20, of Hitchcock's Final Report on Geology of Massachusetts.)

In Pritchard's history of Infusoria, I find two figures representing *N. striatula*, which leave little doubt that ours is the same species. (See Hist. Inf. Pl. 3, fig. 137, 138.) The following interesting remarks with regard to the organs of locomotion in this genus, are also taken from this work.

"In the small pools left by ebb of the tide near Cuxhaven, Dr. Ehrenberg remarked numerous little bodies, apparently similar to *Navicula* (*Surirella*) *elegans* and *N. striatula*, but which from their comparatively very great size and structure of lorica, were easily distinguishable from the latter upon closer examination. One of these ribbed glass-like creatures was, besides its size, remarkable for its great mobility, and Dr. E. was enabled to investigate its system of locomotion much more satisfactorily than he had hitherto done in any of the genus. This organ he states was very different, both in form and size, to what he had before noticed in that genus. Instead of a snail-like expanding foot, *long delicate threads projected where the ribs or transverse marks of the shell join the lateral portion of the ribless lorica, and which the creature voluntarily drew in or extended.* An animalcule one eighteenth of a line long, had twenty-four for every two plates, or ninety-six in the total; and anteriorly, at its broad frontal portion, four were visible. It is probable that this creature may form the type of a special group of the Bacillariæ."

7. *Navicula* ———. (Pl. II, fig. 22.) This small species of Navicula with striate faces, is not uncommon in the infusorial stratum of Richmond, Va.

b. Without transverse striæ.

8. *Navicula* ———. (Pl. II, fig. 23, a, b.) This species is distinguished by having two grooves which cross each other at right angles on the ventral face, presenting a cruciform appearance, and dividing this face into four equal portions, which are without striæ. It is a conspicuous species in many American specimens of fossil freshwater infusoria, and is very common in the living state. I have found it in New York, Ouisconsin and Virginia.

9. *Navicula sigma.* (Pl. II, fig. 24, a, b.) Smooth, carapace lanceolate, sigmoid, not striate, linear, lanceolate on the straight side.

Our figure represents a sigmoid species, found among marine Algæ at Stonington, Conn. A somewhat larger sigmoid species occurs in the infusorial stratum of Richmond, Va.

10. *Navicula?* ———. (Pl. II, fig. 25, a, b.) This very remarkable form I detected among fossil infusoria, from the infusorial stratum of Richmond, Va. It is lanceolate when seen on one side; on the other side it presents the curious outline shown in fig. b.

Note. — This may *possibly* belong to Ehrenberg's new genus Zygoceros, which is described as having a compressed Navicula-shaped carapace; each end provided with two perforated horns. (See Pritchard, l. c. p. 427.)*

In addition to the American species of Navicula above described, Ehrenberg mentions the following as occurring in a fossil state at West Point, namely:

N. alata, *nov. sp.*
N. amphyoxys.
N. Suecica.

I am, however, ignorant of their specific characters; I have met with many species besides those referred to in the present memoir, but omit them, as my present object is to present only the most interesting forms.

EUNOTIA.

Free, single or binary, carapace simple, bivalve or multivalve (siliceous) prismatic, four openings on the same side, two at each end, ventral side flattened, back convex and often dentate, never catenate by perfect spontaneous division.

1. *Eunotia arcus.* (Pl. II, fig. 26, a, b.) Striate, carapace semilanceolate, elongated, two terminal knobs arcuate, eleven striæ in $\frac{1}{100}$ of a line.

* Since this memoir was read, I have ventured to refer this species (Pl. II, fig. 25, a, b.) to a new Genus *Emersonia* founded on this, and a very beautiful living species which I detected in Boston harbor. The genus is named in honor of G. B. Emerson, Esq., President of the Boston Natural History Society. Vid. Boston Journ. Nat. Hist., Vol. IV.

Ehrenberg mentions *E. arcus* as occurring among fossil infusoria from West Point. I presume that our figure, which represents a form very common both in the recent and fossil state in the United States, belongs to this species.

2. *Eunotia diodon.* (Pl. II, fig. 29.) Striate, carapace elongated, ventral side flattened, slightly bidentate at the middle of the back, nineteen striæ in $\frac{1}{100}$ of a line, $\frac{1}{40}$ to $\frac{1}{24}$ of a line.

Hab. West Point, fide Ehrenberg. Probably the same as fig. 29, which is common both recent and fossil at West Point, and elsewhere in the United States.

3. *Eunotia tetraodon.* (Pl. II, fig. 31.) Striate, carapace semilunar, short, flattened or concave on the ventral side, four rounded teeth on the convex back, twenty-three striæ in $\frac{1}{100}$ of a line, $\frac{1}{96}$ to $\frac{1}{48}$ of a line.

Common among fossil infusoria from Manchester, Mass., and West Point, N. Y. The living species occurs at West Point.

4. *Eunotia pentodon.* (Pl. II, fig. 32.) Striate, carapace semi-lunar, short, five teeth on the convex back, twenty-three striæ in $\frac{1}{100}$ of a line.

Fossil at Manchester, Mass. Living at West Point.

5. *Eunotia serra.* (Pl. II, fig. 33.) Striate, carapace linear, slightly curved, twelve to thirteen rounded teeth on the convex back, nineteen striæ in $\frac{1}{100}$ of a line, $\frac{1}{36}$ to $\frac{1}{24}$ of a line.

Our figure is from specimens found fossil in Massachusetts. I have also received it from various other localities.

I strongly suspect that the number of the teeth on the back of the four last described species of Eunotia, is liable to variation, and that the number of species has in consequence been made too great. See remarks in Final Report on Geology of Massachusetts, volume II, p. 310, et seq.

6. *Eunotia* ———. (Pl. II, fig. 27, a, b.) This species was found in water from a brackish ditch in New Jersey, which was sent to me for examination by Dr. Torrey. It is concave on one side, convex on the other, with a slightly elevated and widened portion in the middle. It is also minutely striate.

COCCONEIS.

Free, single, carapace simple, bivalve (siliceous) prismatic or hemispherical, a single opening in the middle of both sides of the carapace (?), never double or catenate by spontaneous division.

1. *Cocconeis?* (Pl. II, fig. 34.) Represents what I believe to be a species of Cocconeis. I found it adhering to a small marine Alga from the eastern shore of Florida. A similar form is abundant in Boston harbor.

Beautiful figures of *Cocconeis* (*Campylodiscus*) *clypeus* drawn by F. Bauer, will be found in Pritchard's Hist. Inf., Pl. 12, fig. 516–518. I have received fine specimens of these elegant fossils from E. J. Quekett, Esq., of London.

BACILLARIA.

Free, (never fixed) carapace simple, bivalve or multivalve (siliceous) prismatic, forming chains or zigzag polypidoms by imperfect spontaneous division of the carapace and perfect division of the body.

1. *Bacillaria paradoxa.* (Pl. II, fig. 35.) — *The standard bearer.* Striate, carapace linear, very slender, often fifteen times longer than broad, yellow, frustules very active, $\frac{1}{96}$ to $\frac{1}{20}$ of a line. Syn. *Vibrio paxillifer, Müller.* See Encyl. Meth. Pl. 3, fig. 16 to 20.

I first detected this species in October, 1840, among Algæ from the Hudson River, near West Point. I am informed by Dr. P. B. Goddard, of Philadelphia, that it also occurs in abundance near that city. It is a very interesting species, presenting by its curious motions and paradoxical appearance, an object well calculated to astonish all who behold it. At one moment, the needle-shaped frustules lie side by side, forming a rectangular plate; suddenly, one of the frustules slides forward a little ways, the next slides a little also, and so on through the whole number, each however retaining a contact through part of its length with the adjoining ones. By this united motion the parallelogram is changed into a long line; then some of the frustules slide together again, so that the form is then much like a standard. Similar motions are constantly going on, and with such rapidity that the eye can scarcely follow them. There are few more interesting objects for the microscope.

Several of the positions of these singular productions are well represented by Müller. (See Encyc. Meth., Vers, Pl. fig. 16–20.) Müller found his specimens abundant on *Ulva latissima;* I found mine pretty common among *Enteromorpha*, *Polysiphonia*, and *Potamogeton*, which grow together in brackish water on the flats in the Hudson River, near West Point.

2. *Bacillaria? tabellaris.* (Pl. II, fig. 36, *a*, *b*.) Smooth, carapace linear, narrow, swollen in the middle, dividing into quadrangular plates of variable length, ovary lobed and yellow, $\frac{1}{96}$ to $\frac{1}{80}$ of a line, (width of filament.) Syn. *Diatoma flocculosum*, Kutz., Linn. 1833, Pl. 17, fig. 67. *Diatoma flocculosum*, Greville, in Brit. Flora, volume V, p. 406.

This species is very common in all parts of the United States which I have visited. It is easily recognized by its zigzag chains, composed of plates (individuals) of various width, which have the middle and two outer edges considerably thickened, as is shown in the side view, fig. 36, *b*.

In fig. 37, *a*, *b*, is represented what I believe to be the full grown state of the species. It at first view appears very distinct from fig. 36; but on examination, we find the same thickening of the middle and ends, and similar transverse lines. The two varieties or states occur together; both are also found fossil. They are very abundant in ditches and ponds near West Point.

3. *Bacillaria marina?* (Pl. II, fig. 38.) This is a *marine* species, which I found at Stonington, Conn., and Staten Island, N. Y., adhering to filamentous Algæ. It is distinguished by having on each half of its frustules two lines, which commence near the centre and run straight and parallel, until they arrive near the extremities, when they suddenly become falcate for a short distance, and then resume their original directions. The curved portions of the lines have some resemblance to the upper portion of a pair of tongs. The position of these lines is very similar to those on *Bacillaria Meneghinii.* (See Schlechtendal's Linnæa, 1840, Tab. IV, fig. 1.

TESSELLA.

Free, carapace simple, bivalve or multivalve (siliceous) prismatic, compressed in form of plates, forming zigzag polypidoms *by imperfect spontaneous division of the body, and perfect division of the carapace. The chains have spontaneous motion.*

Tessella catena. (Pl. II, fig. 39?) Carapace lamelliform, often broader than long, 4-24 longitudinal series of transverse striæ, ten striæ in $\frac{1}{100}$ of a line.

Fig. 39 is copied from a species, of which I found a few individuals adhering to a dried Alga from Stonington, Conn. It appears to belong to *T. catena.*

FRAGILLARIA.

Free, carapace simple, bivalve or multivalve, (siliceous) prismatic, forming chains resembling fragile ribands resulting from the imperfect division of the carapace and body.

1. *Fragillaria pectinalis.* (Pl. II, fig. 40.) Striate, corpuscles broad, two to four times longer than broad, swollen and lanceolate on the lateral side, ovary yellow, $\frac{1}{192}$ to $\frac{1}{36}$ of a line.

The flat riband-like filaments of this species are very common in ponds and slow running streams near West Point, and they often form masses as much as a square foot in extent. The filaments are of a yellowish green color, and resemble flat ribands crossed by transverse parallel lines. Great variety occurs in the size and form of the frustules, but they are generally much longer than wide. Very minute striæ may often be distinctly seen on the edges of the frustules, as represented in our figure, but sometimes it requires a high magnifying power and skilful management of the light to render these apparent.

The masses composed of these filaments dry to a glistening silvery mass, which is exceedingly fragile, and which is unchanged by fire or nitric acid.

This species is not unfrequent in the fossil state, but the chains are then usually broken up.

Pl. II, fig. 41, represents a variety (?) of this species, with very narrow frustules, each of which, when living, was marked with two yellowish spots, (ovaries?) Perhaps this is *F. bipunctata.* It occurs abundantly at Detroit, Mackinaw and West Point.

2. *Fragillaria trionodis.* Ehrenberg mentions this species as occurring in a fossil state at West Point. I am ignorant of its characters, and may have confounded it with *F. pectinalis*, to which species all the varieties occurring at West Point appear referable.

MERIDION.

Free, carapace simple, bivalve or multivalve (siliceous) prismatic, wedgeform, forming fragile spiral chains which often appear like complete circles, and which result from imperfect spontaneous division.

Meridion vernale. (Pl. II, fig. 42, a, b.) Corpuscles wedgeform, striate, anterior end truncate and dentate, polypidom spiral, often appearing perfectly circular, $\frac{1}{95}$ to $\frac{1}{20}$ of a line. *M. circulare, Agardh. M. circulare, Kutzing,* Linn. 1833, Pl. 15, fig. 37.

This is one of the most beautiful of the fresh-water infusoria, and excites great admiration in all who behold its elegant form and markings, under a good microscope. It occurs in immense quantities in the mountain brooks around West Point, the bottoms of which are literally covered in the first warm days of spring, with a ferruginous colored mucous matter, about one quarter of an inch thick, which, on examination by the microscope, proves to be filled with millions and millions of these exquisitely beautiful siliceous bodies. Every submerged stone, twig, and spear of grass, is enveloped by them, and the waving plume-like appearance of a filamentous body covered in this way, is often very elegant.

The spiral or helicoidal form of the chains is not easily perceived, unless the chains are thrown on edge, (as in fig. 42, b.) This is easily effected with Chevalier's compressor.

Alcohol completely dissolves the endochrome of this species, and the solution, when evaporated, leaves a greenish resinous mass. The frustules, after the action of alcohol, are as colorless as glass, and resist the action of fire and nitric acid.

ECHINELLEA.

The section Echinellea contains those Bacillaria which are *fixed*, that is, attached either by their extremities, or by a pedicel, to other bodies. They are all siliceous.

The section Lacernata includes those which have a double covering. They consist of groups of siliceous individuals, surrounded by a common gelatinous mass, or enveloped by a membranous tube.

As many species of each of these sections are often found spontaneously or accidentally separated from their pedicels or tubes, there is great chance of mistaking them for species of Naviculacea.

ISTHMIA.

Fixed by one end, carapace or lorica siliceous, simple; broader than long, catenate by imperfect spontaneous division, individuals making various angles with each other, and connected by a narrow isthmus or neck-like process.

Two species of this genus have been detected, namely, *I. enervis*, and *I. obliquata*. Neither of these have, to my knowledge, yet been detected in the U. States; but as the latter is a pelagic species, which has been found in places so different and distant from each other as Iceland, England, the Canary Islands, Cape of Good Hope, &c., there can be little doubt that it will yet be found growing on some of our marine Algæ. The first specimen which I ever saw, I detected on a dry specimen of *Odonthalia dentata* from Iceland. I have since received fine English specimens from E. J. Quekett, Esq. of London. Few microscopic objects exceed in beauty these little gems of the ocean. I have proved that their carapace is siliceous by the proper chemical tests. A good idea of the general form of this genus may be got from Plate 4, fig. 153, of Pritchard's Infusoria.

SYNEDRA.

Carapace simple, siliceous, fixed when young by one extremity, when older often free, longer than broad, foot either wanting or rudimentary, form elongated or prismatic.

Synedra ——? (Pl. III, fig. 1.) Frustules long, slender, linear, adhering laterally into plates which are supported by a short fleshy pedicel, and terminated by a fleshy mass.

The species whose usual appearance is shown in Pl. III, fig. 1, occurs in vast quantities on various Algæ in the Hudson River at West Point. It usually completely envelopes the plants to which it is attached, giving them a covering of bristling crystal-like particles, through which it is often difficult to see any portion of the supporting plant. When the Algæ on which it grows are dried, they often have a greenish gray hue, from the presence of this parasite.

It presents considerable resemblance to S. *Gailloni*, Ehr. (*Diatoma crystallinum*, Ag.) and has, like that, minute striæ on the edges, but I have seen no allusion made in the descriptions of that species to the fleshy projection which is so conspicuous in our species.

A person who sees how abundant this species is in the recent state, will no longer wonder that, in the lapse of years, masses of infusorial shells should accumulate so as to form extensive strata.

Synedra ——? Pl. III, fig. 2.) Frustules linear, straight, striate, truncate on the lateral side, ventral sides with a neck-like contraction near each end, ends rounded.

This species is very abundant in fresh water near West Point, often covering aquatic plants with a glittering envelope of crystal-like frustules. The individuals are perfectly linear, with truncate ends. When seen laterally, they show near their extremities a slight contraction, which forms a neck supporting the round or knob-like terminations. Minute striæ may be seen as represented in the figure.

This species presents many points of resemblance both to *Synedra ulna* and *Fragillaria rhabdosoma* of Ehrenberg, but I cannot identify it positively with either.

PODOSPHENIA.

Carapace simple, siliceous, cuneiform, fixed when young by one end, afterwards often free, longer than broad, pedicel small, hemispherical, or wanting.

In Pl. III, fig. 3, is represented a species which agrees with the above generic characters, and which I therefore place here, although it is a fluviatile production, while all of Ehrenberg's species are marine. It invests stones, &c. in small streams near West Point with a yellowish green covering, which appears like a mere stain, but which when scraped off with a knife, is seen to be composed of excessively minute frustules resembling those of Gomphonema, but which have no perceptible pedicel.

GOMPHONEMA.

Carapace simple, siliceous, cuneiform, fixed upon a distinct filiform, branching pedicel, dichotomous by spontaneous division.

1. *Gomphonema minutissimum.* (Pl. III, fig. 4.) Smooth? corpuscles cuneiform, curved, clavate, $\frac{1}{144}$ to $\frac{1}{72}$ of a line.

A minute species agreeing closely with Kutzing's figure of G. *minutissimum*, (see Linnea, 1833, fig. 43,) occurs abundantly on various aquatic plants in the Hudson River at West Point. It varies much in size; fig. 4, *a*, shows the largest individuals, and fig. 4, *b*, the smaller ones.

2. *Gomphonema* ———. (Pl. III, fig. 5, *a, b.*) This large and beautiful species appears to be related to G. *dichotomum* and to G. *geminatum*, but I am unable to satisfy myself of its identity with either. I found it in vast quantities at the Island of Mackinaw, Straits of Michilimackinac, on a large cedar tree which was sunk in water ten or fifteen feet deep, and which was literally covered with large waving bunches of a yellowish white color, composed of the dichotomous filaments of this species, glittering with crystal-like particles.

The individuals are striate, with one side cuneate, and showing at the broad end two interior arcuate folds; the other side is elongated, obovate or clavate, with a central circular spot and longitudinal smooth portion. The pedicel is repeatedly dichotomous.

3. *Gomphonema acuminatum?* (Pl. III, fig. 6.) Striate, corpuscles elongated, wedgeform, end swollen and pointed, contracted on the side.

The small species (fig. 6) agrees pretty well with the above characters. It is common in ponds near West Point. I have also seen it in several American specimens of fossil infusoria.

4. *Gomphonema* ———. (Pl. III, fig. 7.) Frustules smooth, geminate or in fan-shaped groups, one side elongated, wedge-shaped, truncate; the other side obovate; pedicel repeatedly dichotomous. Marine.

I have examined this species only in a dry state, having first noticed it on a glass slide on which I had preserved some specimens of *Echinella flabellata* from Stonington, Conn.

The figure is drawn from the dry specimens.

ECHINELLA, *Ehr.*

Carapace simple, siliceous, fixed at one extremity to a pedicel, wedgeform, longer than broad, fan-shaped or verticillate by spontaneous division.

1. *Echinella flabellata.* (Pl. III, fig. 8.) Smooth, corpuscles linear, cuneiform, truncate, slightly three-toothed, striæ longitudinal, one tenth of a line without the pedicel. *Lichmophora flabellata, Ag.* Greville, in Hooker's English Flora, V. p. 408.

This beautiful marine production presents, in its fan-shaped groups of crystal-like corpuscles, an exceedingly elegant appearance. The fans are supported by long, flexible clavate pedicels, which are grouped together in large bunches covering filamentous marine Algæ and Zoophites.

I found it quite abundant at Stonington, Conn. in July. It is said to occur also at Scotland, Venice, and at the Cape of Good Hope.

2. *Echinella* ———. (Pl. III, fig. 9.) Corpuscles smooth? lanceolate, truncate; pedicel short, broadly clavate, often nearly circular, supporting the radiating, closely aggregated corpuscles.

I detected this very elegant species about a year since in the Hudson River near West Point, where it grows upon Potamogeton, Enteromorpha, &c. It agrees in many respects with E. *fulgens*, Grev., but that is described as being striate, a character which I have not perceived on our species.

COCCONEMA.

Carapace simple, bivalve or multivalve, siliceous, fixed by one end, pedicellate, longer than broad, pedicel in the direction of the axis of the body. (*Pedicellate Naviculæ.*)

When separated from their footstalks, there is no good character to distinguish them from Navicula; but the unsymmetrical boat-shaped frustules of Cocconema will *generally* serve to identify them.

1. *Cocconema* ———. (Pl. III, fig. 10.) Carapace lanceolate, ends obtuse, pedicels repeatedly dichotomous, secondary branches articulated to the primary ones. Striæ were not perceived.

Abundant in the Hudson River at West Point. It appears to be allied to C. *lanceolatum* of Agardh.

2. *Cocconema* ———. (Pl. III, fig, 11, *a*, *b*.) These figures represent two positions of a species of Cocconema which is very common in the living state near West Point, and which also abounds as a fossil. In the living state I have but rarely seen it attached to a pedicel. It is generally free, and moves about spontaneously like a Navicula.

I once, on a cold day in October, noticed vast collections of this species which were enveloped in a mucous covering, and which formed large cloud-like masses, several inches in extent, investing aquatic plants, stones, &c. Each of these masses was crowded with millions of the siliceous shells of this species.

Ehrenberg mentions C. *asperum* as a new species detected by him among the fossils from West Point. I am ignorant of its distinguishing features.

ACHNANTHES.

Carapace simple, bivalve, or multivalve, siliceous, prismatic, longer than broad, fixed by one end, pedicellate, pedicel oblique, ventral, always simple, opening in the middle of the body. Groups, *resulting from increase by spontaneous longitudinal division, resembling chains, little banners, plates or ribands.*

Achnanthes brevipes. (Pl. III, fig. 12.) Corpuscles striate, curved in the middle, ends rounded on the dorsal and ventral sides; pedicel thick, shorter than the body.

I first noticed this species on filaments of *Conferva fracta* from Providence Cove, R. I., and have since found it abundant on marine Algæ from Stonington, Conn. Small specimens, differing I believe in no essential character, are also very abundant on aquatic plants in the Hudson River at West Point.

The *Achnanthes longipes* of authors may be a distinct species, but the distinction "pedicel longer than the body," appears to me to be founded on a character liable to much variation. I saw specimens at Stonington having pedicels much longer than the body, yet they appeared to me to agree with E. *brevipes* in every other respect.

STRIATELLA.

Carapace simple, (siliceous,) fixed by one end, longer than broad, or nearly square, obliquely pedicellate in form of little flags, corpuscles without openings in the middle, often forming zigzag chains by spontaneous divisions. (Stipitate Bacillariæ.)

1. *Striatella arcuata.* (Pl. III, fig. 13.) Carapace lamellar, nearly square, with three to seven longitudinal internal lines, transversely striate, polypidoms (flags) in form of ribands, often curved, nine striæ in one one-hundredth of a line. *Diatoma unipunctatum,* Agardh, Greville, &c.

This species occurs in vast quantities on filiform marine Algæ at Stonington, Conn. It covers the plants in such profusion as to make them glitter in the sunbeams as if covered with crystals. The recent frustules are not flat, but slightly convex, and are usually marked with an internal nearly circular spot, which in my specimens was yellow, not rose-colored as usually described. Considerable variation in the width of the frustules occurs even in the same riband. Each plate is transversely striate, the alternate lines not quite reaching to the edge. I saw numerous specimens supported by long pedicels.

LACERNATA.

Frustulia, *Ehr.*

Envelope double, carapace siliceous, mantle gelatinous, amorphous, corpuscles scattered or in groups.

I have seen no American species of this genus.*

SYNCYCLIA.

Envelope double, exterior mantle gelatinous, carapace siliceous, navicula-shaped, forming by spontaneous division, circular groups surrounded by gelatine. See Pritchard's Infusoria, Pl. 4, p. 206, No American species has yet been detected.

NAUNEMA.

Envelope double, carapace navicula-shaped, siliceous; mantle gelatinous, exterior, tubular; tubes filiform, separate, branching, confervoid, resulting from perfect division of the carapace, and imperfect division of the mantle.

In this genus, corpuscles which cannot be distinguished from those of Navicula are assembled together in vast numbers, in flexible membranous tubes, within which they may often be seen to move freely. They doubtless often leave these tubes, and then appear like species of Navicula.

I have noticed several American species, but I am unable to decide whether they are identical with any hitherto described, as I have had very little opportunity to study our species in a living state, and have no foreign specimens or figures to compare them with. I shall therefore content myself with merely giving the forms of the frustules found in each species, and such additional particulars as seem most interesting.

1. *Naunema* ———. (Pl. III, fig. 14.) The figure represents corpuscles from a branching species found on the shores of Staten

* My opportunity to study the marine Bacillaria, has been very slight. I presume, therefore, that many marine forms not noticed by me during the two days which I spent at Stonington will yet be detected, and among them will probably be species of Frustulia, Syncyclia and Schizonema.

Island, N. Y. The tubes are whitish, containing long rows of corpuscles, strung end to end, each of which contains two round globules looking like air-bubbles. No trace of striæ.

2. *Naunema* ———. (Pl. III, fig. 15.) This figure shows the form of corpuscles which filled short robust unbranched filaments, which were exceedingly lubricous. Bunches of filaments about half an inch in length, were found in great abundance on Zostera, &c. at Stonington, Conn.

3. *Naunema* ———. (Pl. III, fig. 16.) This figure shows the outline of dried corpuscles from a specimen obtained at Stonington, Conn., where it is very common. Its filaments are branched, and form larger and longer bunches than the preceding, with which it occurs.

4. *Naunema* ———. (Pl. III, fig. 17.) This is from specimens found in immense quantities in the Hudson River, at West Point. The masses have not the green color of the two preceding species, but present a rich brown color. The frustules are in all respects like those of Navicula, and I have often seen them move spontaneously in their tubes, some going one way and others another.

In Pl. III, fig. 17, *a*, is shown the outline of much longer frustules, found in tubes similar to those just mentioned.

GLOEONEMA.

Envelope double, carapace siliceous, mantle tubular, tubes simple, often branched, corpuscles curved, resembling COCCONEMA *in a tube.*

Mr. Berkely has recently published (Ann. and Mag. Nat. Hist. Vol. 7, p. 449) some interesting observations, by which he appears to have proved that the only species of this genus, the singular *G. paradoxum*, consists merely of rows of ova of some aquatic insect. He watched their developement into larvæ. I have not seen American specimens.

SCHIZONEMA.

Envelope double, carapace siliceous, mantle tubular, tubes united in bundles, split in some places so as to appear branched, corpuscles like those of NAVICULA.

No American species has yet been detected by me.

It was my intention, when I commenced the above sketch, to give in connection with it, an account of all the American localities of fossil infusoria, but further reflection has convinced me that this labor is unnecessary. All our fluviatile deposits of fossil infusoria, contain nearly the same species, and all these species are now living. From the great range which the living species have been shown to have in our country, there is great probability that all of the siliceous ones may be detected, if carefully sought for in any of the specimens of fresh-water infusorial deposits. As for the localities at which these fossil infusoria occur, it does not appear that a particular enumeration is necessary. The living animals inhabit in great quantities almost every place where water remains several months in the year; their indestructible shells are therefore to be found in greater or less quantity in the sedimentary deposits of all our bogs, ponds and slow streams. These deposits are most remarkable beneath peat bogs, where they constitute strata many feet in thickness, and of great extent, often composed entirely of the siliceous carapaces of animals so minute that millions of them exist in a cubic inch. The "siliceous marl" which they form, is often so white and light as to be mistaken for magnesia, and Dr. Jackson states that it has actually been sold as such to apothecaries, who were much surprised when informed by him that not a particle of magnesia was present.

Among the vast number of fluviatile localities now known, I think it necessary to allude only to the following, namely: West Point, from which specimens have been examined by Ehrenberg, whose list of the species is given in Silliman's Journal, volume xxxix, p. 193; Blue Hill Pond, and various other localities in Maine, discovered by Dr. Jackson; Manchester, Spencer, Wrentham, Bridgewater, Andover, &c., in Massachusetts, discovered by Prof. Hitchcock; and Smithfield and other places in Rhode Island, discovered by Owen Mason, Esq. The largest and most conspicuous species from all these localities are Navicula viridis, Pl. II, fig. 16, Navicula ——? Pl. II, fig. 23, Cocconema ——, Pl. III, fig. 11, Eunotia arcus, Pl. II, fig. 26. With these occur various smaller species, and numerous siliceous spiculæ of fresh-water sponge, Pl. III, fig. 18, *a* to *d*, and other siliceous bodies of organic origin, such as the *Amphidiscus rotula* of Ehrenberg, Pl. III, fig. 20, and others whose nature is unknown, but which I suspect to be of vegetable origin, perhaps prickles of aquatic grasses. See Pl. III, figs. 21, 22 and 23.

The most interesting American deposit of fossil infusoria, is the "infusorial stratum" discovered by Prof. W. B. Rogers, of the University of Virginia. It is peculiarly interesting from its vast extent, the beauty of its species, and from its belonging to the marine tertiary formations. All other American fossil infusoria yet discovered are of fluviatile origin, and of the most recent date.

I have already pointed out the striking correspondence between the fossils of the infusorial stratum of Virginia with those of Oran in Africa. This is shown by the occurrence of vast quantities of various species of Coscinodiscus and Actinocyclus, with Gaillonella sulcata? &c. Believing that it will be of great interest to geologists both at home and abroad to trace out this correspondence of the fossils of regions so far distant, and of beds which are at present referred to different epochs,* I have added to my plate 3d, a number of figures of siliceous bodies not before described, found in the infusorial stratum of Virginia. The following is a brief account of these bodies.

In Pl. III, fig. 24, *a*, *b*, *c*, are shown different views of small siliceous bodies, which are quite frequent in the infusorial deposits both of Richmond and Rappahannock cliffs. They consist of a concave rhomboidal body, formed of open work, or with large perforations, and having at the extremities projecting spines. I suspect that these belong to the genus Dictyocha of Ehrenberg, several species of which occur at Oran, Caltasinetta, &c.†

Pl. III, fig. 25, shows a siliceous ring with projecting spines; it is possibly a fragment of the preceding.

* Ehrenberg refers the infusorial conglomerates of Oran, &c., to the *chalk* formation, but Rozet considered them as *tertiary* deposits, and Prof. Rogers states that the beds discovered by him separate the *miocene* from the *eocene* tertiary beds of Virginia.

† Since the above was in type, I have seen Ehrenberg's figures of several species of Dictyocha in the Berlin Transactions, and find them to agree with the bodies above referred to.

Pl. III, fig. 26, shows a circular ring connected with a concentric hexagon by six rays proceeding from the angles of the hexagon. The spaces within the hexagon and below the rays are perforations. It is possibly another species of *Dictyocha*. It occurs occasionally among fossil infusoria from Richmond and Rappahannock cliffs.

Pl. III, fig. 27, shows a curious fragment, apparently siliceous, having a campanulate form with a projection at the apex, and pierced with large holes. Fig. 28 shows an ovoid body perforated by similar holes. Of the nature of these curious fossils, I am entirely ignorant. They occur with the preceding.

Pl. III, fig. 29, shows a triangular binary siliceous body, resembling some of the fluviatile species of *Euastrum*. The surface is covered with minute dots, some of which form lines leading from the centre to the angles. Perhaps this belongs to Ehrenberg's genus *Triceratium*, of which species occur fossil at Oran, and living in Cuxhaven.

In Pl, III. figs. 30 to 35 show siliceous bodies which are quite abundant with the preceding forms, and which I suspect are spiculæ of marine sponges. Many of them show a central perforation, like that in the spiculæ of *Spongilla*.*

Other interesting forms occur in the infusorial strata of Virginia, but the limits of this paper will not allow me to present any more of them at present. I have transmitted specimens from Richmond to Ehrenberg, and he will doubtless determine to what extent the African and American beds agree in their microscopic fossils. As the infusorial strata of Virginia belong decidedly to the tertiary epoch, and yet appear to agree remarkably with what Ehrenberg considers as chalk marl from Oran, a revision of the evidence upon which the siliceous infusorial conglomerates of Africa and the south of Europe were referred to the cretaceous group, appears necessary. Should the true age of either the American or African deposits be determined by means of the fossil infusoria, it will be an additional instance of the importance of this

* I have reason to believe that similar siliceous spiculæ occur in vast quantities in the external rays of some species of Actinia.

branch of microscopic paleontology. It has been well remarked that the microscope is now as important an instrument for the geologist as the hammer; and indeed the results obtained by microscopic observation of coal, fossil wood, teeth, polythalamia, and infusoria, prove the truth of this remark. The question *cui bono?* to what useful end are your pursuits? can now be triumphantly answered by the lover of microscopic research; but happily, to use the words of the Hon. W. H. Harvey,* the class who now ask this question to naturalists "is neither so numerous or respectable as it was thirty years ago; it is becoming every day less so, and will soon be confined to the ignorant and the sensual." In the language of another distinguished philosopher,† "the time is past when the utility or dignity of such pursuits can be affected by a sneer at the littleness of their objects, as they seem little in the eyes of the indifferent and the ignorant. Every thing is great or small only by comparison; the telescope teaches us that the world is but an atom, and none know better than microscopical observers that every atom is a world."

THE PHENOMENA OF DRIFT, OR GLACIO-AQUEOUS ACTION IN NORTH AMERICA, BETWEEN THE TERTIARY AND ALLUVIAL PERIODS. BY EDWARD HITCHCOCK, LL.D., *Professor of Chemistry and Natural History in Amherst College, Massachusetts.*

ALTHOUGH the leading facts respecting the *Drift*, or *Diluvium*, of this country, have long ago been given to the world by our geologists, yet the new light which the recent labors of such men as Charpentier, Agassiz, Lyell, Buckland, and Murchison, on the other side of the Atlantic, have shed on the subject, will enable us, I fancy, to classify the phenomena more accurately, and per-

* Manual of British Algæ, by the Hon. William Henry Harvey.

† Richard Owen, Esq. Address before the Microscopic Society of London, 1841.

haps make some advance in theory. This subject is one which must necessarily be last in the order of geological study, because the geologist must be thoroughly acquainted with the subjacent rocks, before he can decide upon the origin and dispersion of that deposit, which is made up of the spoils of all the formations beneath it. In the present paper, I propose to describe the phenomena of our drift, especially as they have fallen under my own observation, and then inquire how far they may be explained by any legitimate theory.

Let me however anticipate so much as to express the conviction, that nearly all geologists would agree in the principle, that the phenomena of drift are the result of the joint and alternate action of ice and water. And I regard this as the greatest advance which has been made of late on this subject. I use the term *Glacio-Aqueous* to express this joint and alternate action, not because the term suits me, or because I expect others will adopt it, but because I cannot devise a better. The proof of such an action I shall present as I proceed.

The phenomena of drift will be arranged in this paper under the following heads:

1. Transported Bowlders.
2. Smoothed, polished, and striated Rocks.
3. Embossed Rocks. (*Roches moutonneés.*)
4. Valleys of Erosion.
5. Moraines.
6. Detritus of Moraines.
7. Deposits of Clay and Sand.
8. Contortions of the Stratified Deposits.
9. Terraced Valleys.
10. Fractured Rocks.
11. Organic Remains.

1. Transported Bowlders.

The character of our bowlders shows them to correspond very exactly with those so accurately described in the northern parts of Europe. They are usually more or less rounded by attrition, but frequently merely by the scaling off of their angular parts by disintegration. A more important fact in respect to many of them, is, that at least on one side, the surface has been smoothed and striated. This may admit of explanation in two ways:—First, the attrition may have taken place before the bowlder was raised from its original bed. Secondly, it may have been produced while the bowlder was frozen into the bottom of masses of ice, grating along a rocky bottom. The latter supposition corresponds best with another fact, not uncommon, namely, that the edges of the bowlder, contiguous to the striated surface, are also rounded. The effect may, however, have been produced sometimes in one way and sometimes in another.

The size of some of our bowlders is very great. Those from ten to fifteen feet in diameter are very common. Those from twenty to twenty-five feet are less common. I have seen several, as at Gay-Head and Bradford in Massachusetts, and in Winchester, in New Hampshire, fully thirty feet in diameter; and one of conglomerate existed a few years ago, but is now a good deal blasted away, at Fall River, in Massachusetts, which must have weighed not less than fifty-four hundred tons, or ten millions eight hundred thousand pounds. I also recently measured one in Antrim, in New Hampshire, whose horizontal circumference is one hundred and fifty feet, and consequently its size must nearly equal that at Fall River; although the vertical circumference in both these bowlders is probably somewhat less than the horizontal.

This country has now been examined with sufficient care, over a breadth of longitude of more than two thousand miles, namely, from Nova Scotia, through New England, New York, the Canadas, Ohio, Michigan, Illinois, and the region west of the lakes, nearly to the Rocky Mountains, to make it certain, that the general direction in which the bowlders have been carried is southeasterly. The greatest part of the force by which they have been transported, has been confined between a south and southeast direction. There are exceptions, indeed, to this statement, as in the St. Lawrence valley and in western New York; where the course was considerably to the west of south. It is somewhat so in limited spots in New England; and on the west slope of a hill in Putney, Vermont, I noticed furrows running S. 35° W. and N. 35° E. by the compass: that is, about 27° west of the true meridian. But such examples are very few compared with those where the same operated southerly and southeasterly. In Europe, as in Switzerland and Scotland, high mountains seem to have formed lines, or centres, from which the bowlders were dispersed in various directions. But in this country no such centres have yet been discovered.* The bowlders have been carried obliquely across our highest mountains; but have, in no case yet known, radiated from them. Indeed, we have reason to conclude that no such case occurs on the continent, unless it be very far to the north; as I shall endeavor to show further on.

As a general fact, bowlders are found largest and most numerous, nearest to the parent rock from which they have been abraded. Thence they decrease in size and number in a southeasterly direction; becoming also more thoroughly rounded, until at length they are reduced to pebbles and sand. At the distance of many miles from the parent rock, we find the detritus occupying a somewhat wider space than the rock; but in general, such a divergence is very slight, and the parallelism of the lines along which the bowlders moved is remarkably preserved.

An important exception to the above statement, respecting the decrease in size of bowlders as we recede from the parent rock, ought here to be noticed. Occasionally and not unfrequently we meet with insulated bowlders, perched perhaps upon the crest of a mountain, or lying in the midst of a deposit of sand, in such a manner as to show that they could not have been pushed along the surface by a *vis a tergo*, but must have been lifted from their original place and borne along above the surface to their present situation. Such bowlders too must often have been carried across very deep valleys. Indeed, such has been the case with most of the transported bowlders in this country. We are yet without maps sufficiently accurate to give a correct idea of the surface of

* *February*, 1843. Professor VANUXEM, in his able Report on the Third Geological District of New York, just published, expresses a different opinion; and he refers to Prof. EMMONS as having found drift radiating from the high mountains of Essex county. But on recurring to Prof. Emmons' Report, also just published, I understand that gentleman to refer all accumulations which he considers proper drift, to a northern origin; and I do not see how the facts subsequently stated in this paper, concerning the White Mountains, can be reconciled with the theory which makes that mountain a centre of dispersion.

this continent. But it may be stated in general, that the predominant direction of our mountain ridges and the correspondent valleys, is either north-north east and south-south west, or nearly north and south. The former course embraces the Apalachian mountains, extending nearly parallel to the coast through most of the middle and southern States, and embracing also the principal ranges of New England, especially the White Mountains. The north and south ridges embrace the Green and Hoosac Mountain chain, and several minor ridges in New England. Now it is obvious, that since the force which transported our bowlders took a southeast direction in general, it must have carried them obliquely across most of our mountain ridges. And this is one of the most striking facts in the phenomena of drift in this country. For I think I have probable evidence that they were carried over our highest mountains; and when one stands upon a precipitous ridge, three thousand, or four thousand, or even five thousand feet high, and sees in the bowlders around him, and in the furrows on the rocks beneath his feet, evidence that this denuding and transporting force has been exerted even at that height, and consequently has swept over all the lower yet lofty ridges that fill his circle of vision, he cannot but feel that the agency, whatever it was, has been wide-spread and gigantic.

The facts which have been stated respecting the dispersion of bowlders from the parent rock, appear to me inexplicable without calling in the joint agency of ice and water. Nor does it appear sufficient to suppose that the water simply lifted up and bore away masses of ice loaded with fragments of rocks. For suppose a particular spot to be covered with ice, adhering firmly to the surface. Water, flowing in among the ice, would lift up its masses and float them away as icebergs, which would drop their load of detritus as they melted away, and thus the insulated bowlders and those crowning the ridges of mountains, would be most satisfactorily accounted for. But this action would not account at all for those larger and more numerous bowlders found near to the original rock, nor for that powerful abrasion and furrowing which the unbroken ledges exhibit. These phenomena, however, would be the result of crowding huge masses of ice over the spot. These would break up and round blocks of the formation, and strew them along the surface, carrying of course the lightest the farthest. But if this were the only mode of their dispersion, we should expect that the greater part of them would be found crowded together in the first deep valley in a southeasterly direction from the original rock. But in fact we do not usually find them there, though it must be acknowledged that the northern slopes of hills are frequently more strewed over with them than the southern side. This we should expect, if many of them were conveyed by huge icebergs, whose lower extremity, striking against these hills, would drop many blocks. Upon the whole, the phenomena of the dispersion of bowlders are best explained, by supposing a part of them floated along the surface of a current, attached to icebergs, and a part of them urged forward, *pell mell*, by ice, grating along the surface. The latter effect might to a certain extent result from the mere expansion of a mass of ice without aqueous currents. But that currents of water were concerned, where bowlders have been carried four hundred, or five hundred, or even one hundred miles, cannot be doubted; and to this extent at least have they been transported in the central parts of our country. Besides, the uniformity in the direction taken by our bowlders, agrees far better with the idea of currents of water, than any other agency.

The removal of bowlders from lower to higher levels is another fact of great importance in the history of our drift. It is an extremely difficult point to ascertain precisely how much they have been raised from their original situation, because it may be that the original rock, now scattered in bowlders over lofty ridges, may once have constituted ridges much more elevated than at present. When, however, the transported rock is considerably newer than that over which it is scattered, the presumption is, that the former always occupied the lowest level. Let us take for example the bowlders of quartz and Silurian rocks found strewed over the primary strata of the Green and Hoosac Mountains, and the Highland chain extending through New York and New Jersey. Excepting a few limited peaks of these rocks, as the hill of quartz called Bald Mountain in North Adams, and the sandstone mountain called the Catskills, west of the Hudson, these formations do not rise as high as the primary ranges over which their bowlders are scattered, by at least one thousand feet; and I am confident that every one acquainted with the topography of that region, will admit that it is a moderate estimate to say, that these bowlders must have been elevated from their original position as much as one thousand feet. I doubt not that many of them have been raised twice that quantity.

It would be easy to multiply examples of this transference of bowlders from lower to higher levels, where the height is less; as in a multitude of instances in the eastern part of Massachusetts, where a coarse conglomerate is strewed over the higher adjoining unstratified ranges; and in the valley of Connecticut river, where syenite and sandstone bowlders are found upon the narrow crest of Holyoke and Tom, having been detached from the ledges several hundred feet below. But the example already described is far more extensive, reaching from Vermont through Massachusetts and Connecticut, into New York, and probably further southwest, and is sufficient. The fact I believe will not be doubted; but it seems to me that its explanation on any known hypothesis, is one of the most difficult in the whole history of this subject. It is needless to spend time in showing that mere currents of water, however violent, never could have done it. The question remains whether icebergs, loaded with bowlders, and floated by water, can have accomplished the work. But this question will be more advantageously examined after detailing some other phenomena of drift.

It is not easy to give a correct idea of the vast quantity of bowlders scattered over some limited districts of New England. The surface is sometimes almost literally covered with them; as the sketch (Pl. VIII, fig. 1) taken near a place called Squam, on Cape Ann, in Massachusetts, will show. The country there for miles around, is almost equally full of bowlders and barren of vegetation: and I might point to a multitude of other places, particularly in the eastern part of Massachusetts, equally crowded with bowlders.

2. Smoothed, Polished, and Striated Rocks.

The facts under this head form a most important element in the history of American drift. And yet they are more easily overlooked than those respecting bowlders: nor can they be fully appreciated but by long continued and careful observation. It requires a good knowledge of the stratification, lamination, jointed structure, segregated ridges, and peculiarities of disintegration in different rocks, not to mistake these phenomena for striæ and furrows. Then it must be remembered, that where rocks have been for ages exposed to atmospheric agency, most of them have suffered so much disintegration, as to obliterate all superficial smoothing and furrowing; or they are so coated with lichens as to conceal such effects from superficial observation. But if any one will always have an eye open for noticing the surfaces of rocks, he will find many places, where neither the atmosphere nor vegetation have been able to obliterate the traces of some powerful agency. Coarse granite, gneiss, mica slate, and granular limestone, thus exposed, will, indeed, rarely retain them; but the finer slates, whether micaceous, talcose, or argillaceous; some of the harder compact limestones, the fine grained syenites and traps, some sandstones, and most conglomerates, seem almost to bid defiance to the disintegrating agency of the atmosphere, and retain these markings as fresh almost as if made yesterday. This is especially the case when they have been protected by a few feet of soil; so that the geologist will find the best examples where roads, rail-roads, canals, and other excavations, have laid bare new surfaces. In some cases, which have been particularly described by Professors Dewey, Emmons, and Locke, in New York and Ohio, the surface of hard limestone, over large areas, has a polish almost equal to that of marble. The syenite and porphyry of Essex county, in Massachusetts, exhibits a polish almost equally good. Where the excavations for the Eastern rail-road have newly uncovered these rocks, about three miles south of Newburyport, also a little north of Ipswich, and between Salem and Lynn, good examples may be seen on the east side of the road. I have noticed, also, a good example connected with striæ, on the argillaceous slate at the quarry in Harvard, Mass., and a still better one on the same rock in the east part of Guilford in Vermont, where this rock is as nearly polished as its nature admits. In all cases, however, these polished surfaces contain more or less of striæ.

When these abrasions appear on ledges facing the northwest, that side of the rock is more or less rounded, and in many cases, where portions of the rock rise above the general surface, a similar appearance exists, which I shall describe more particularly further on. But in general, the producing cause seems to have acted like a huge plane, sweeping off the salient parts of the rock, and leaving the hollows mostly untouched. And this is one of the marks by which this agency is strikingly distinguished from the action of mere currents of water. I will here refer to a well-known locality, where the effects of these two agencies may be seen in close juxtaposition. It is Bellows Falls, in Connecticut river, between New Hampshire and Vermont, especially on the Vermont side. The hard gneissoid rock at this place, shows on its surface many distinct examples of the smoothing and striæ above described, while the sides of the deep gorge, which the river has formed through the ledge, present no less striking examples of such aqueous agency as is now in operation on the globe. The first-named agency, which I call glacio-aqueous, seems to have operated like a large heavy body, armed on its bottom with gravers, driven along the surface with a prodigious force, grinding down the prominences, but not conforming to the sinuosities. On the other hand, the running water has produced almost every possible variety of curved surface in the rocks, which are smoothed almost to a polish, but rarely if ever distinctly striated. Close to the western extremity of the bridge over Connecticut river at this spot, may be noticed some rocks rounded and striated by glacio-aqueous agency; and the contrast between this and mere aqueous agency may here easily be noticed. In Pl. VIII, f. 2, I have given a sketch of these rounded and striated rocks, not because it is a very striking example, but because it is so easily found by the traveller.

Rocks exposed to the action of breakers upon the sea coast, exhibit less of irregularity of surface than those at such a spot as Bellows Falls, and especially are they usually wanting in what are called *pot holes.* Nevertheless, they appear widely different from those which have been subjected to glacio-aqueous agency. The former rarely show any striæ; or if occasionally produced by bowlders, or ice, driven over the surface by powerful storms, the markings are wanting in that parallelism which is so characteristic of glacio-aqueous action. In short, although it was natural before we were made acquainted with any other agent that could produce the smoothing and striæ of rocks connected with drift, to impute them to currents of water, yet a careful examination has satisfied me, not only that they can almost always be distinguished from the effects of running water and of breakers, but that they are totally inexplicable by such causes; although I doubt not that currents of water have been concerned in their production.

The remarkable parallelism of these striæ is another fact inexplicable on the supposition that they were made by drift urged over the surface by mere currents of water. Their direction in different districts of country, does indeed differ many degrees. But in a given district, the manner in which they retain their parallelism, over very irregular surfaces, is a striking peculiarity. You will, indeed, sometimes see them turned aside a few degrees where they pass over a very salient rock. But more commonly they hold on their undeviating course, whether it carries them directly towards the summit of a hill, or obliquely along its sloping sides. Now it is most obviously impossible that matters driven along promiscuously by currents of water, should produce such effects. But suppose vast masses of ice, with bowlders frozen into the bottom, to grate over the surface by expansion, or by currents bearing them along, and this parallelism of the resulting striæ would be just what we should expect.

I have just alluded to striæ existing on the sloping sides of rocks; and this point demands some further details. It has, however, only of late attracted my particular attention; and, therefore, I cannot give as many facts concerning it as its importance demands. As a general fact, it is only the northern and northwestern slopes of mountains that are thus smoothed and striated. I have seen a few cases, however, in which a gentle southeastern declivity exhibits these markings; as on the road from Windsor, in Massachusetts, to Cummington; and the southern side of the summit of Mount Monadnoc in New Hampshire, shows them on a much steeper slope. But on the northwestern side of mountains they are much more distinct, and frequently commence three hundred or four hundred feet below the summit: nay, I am inclined to believe in some instances, at a much lower level. Examples of this sort occur all along the steep western side of the Taconic range of mountains, forming the western boundary of Massachusetts. In passing from Peru to Worthington, we ascend (I believe in the eastern part of the former town,) a long but gentle slope, thus smoothed and furrowed. This is near the highest part of the Hoosac Mountain range in Massachusetts. Another example I noticed in passing from Worthington to Middlefield, where the slope was much steeper. Mount Everett is a rounded eminence connected with the Taconic range, in the southwest corner of Massachusetts, about two thousand six hundred feet high, and very steep on its northern side. Yet striæ occur there several hundred feet below the summit. Finally, they are distinct on Monadnoc; and some portions of the surface where they appear, slope as much as sixty or seventy degrees. This is near the summit, where, it ought to be stated, is more irregularity in the direction of the striæ than I have witnessed elsewhere.*

Now did we find these striæ all pointing to the summit of the mountain as their centre of radiation, and an accumulation of detritus at the foot of the mountain, we might infer that the force acted downwards and not upwards. But in general, the striæ seem to have no reference to the summit of the hill, and their course leads along the face of the hill at every degree of obliquity, while the detritus detached by this agency, will be found carried

* *January* 1, 1843. In Mr. DARWIN's Paper *on the Ancient Glaciers of Caernarvonshire*, in the New Ed. Phil. Journal for Oct. 1842, p. 362, I have just seen a case of striæ described analogous to that on Monadnoc. "On one particular face of the rock," says he, "inclined at an angle of somewhere about fifty degrees, continuous, well-marked and nearly parallel lines sloped upward, (in a contrary sense to the surface of the glaciers,) at an angle of eighteen degrees with the horizon."

away southeasterly. At least, I have found no exception to this general fact; and this abrasion on the northern slopes of mountains must, therefore, have been produced by some body moving up the slopes in a southeasterly direction. This surely will not be imputed to mere currents of water, pushing along detritus; because in this way it must have been forced around, not over, the hills. Could immense icebergs have been stranded on the northern slope of the hill, and afterwards, by the force of currents, have been driven over the summit? Or would it be necessary to suppose, that after the stranding, the water must have risen so as to lift up the iceberg? Or would a vast sheet of ice, lying upon the earth's surface, by mere expansion, without the presence of water, have been able to produce the smoothing and furrowing in question? I shall not here attempt to decide between these hypotheses; but I think we may decide that ice was concerned in the process.

It has been stated as a general fact, that the striæ are remarkably parallel. But on some surfaces we find two sets of these striæ, which make a small angle, say between fifteen and twenty degrees with each other; although in each set the lines are parallel to one another. And usually, one set is much fainter than the other. Some striking cases of this sort have been given by Professor Locke in his Report on the Geology of Ohio.

Such cases as the above, teach us that the force producing striæ, was exerted on the same spot more than once, and in a different direction. Such would be the precise effect of forcing successive masses of ice over the same surface: such is the effect produced at the present day by advancing glaciers in the Alps; as we learn by the lucid descriptions of Agassiz. I have never seen a third set of striæ on the same surface: not, as I suppose, because the force producing them was not applied three times in the same spot, but because the earlier striæ would soon be obliterated. For one cannot observe how deeply the surface has often been eroded by this agency, without being satisfied that the work has required hundreds, nay thousands of repetitions in the producing cause.

The smoothing and furrowing which have now been described, occur at all altitudes, from the tops of our highest mountains to the bottom of our deepest valleys; and what is most remarkable, is, that the direction of the striæ is often the same at all altitudes. It is, indeed, true, that in some valleys we find their course considerably changed; showing, that at a certain stage of the process, the force was more or less diverted into these valleys, and this is particularly true of the larger valleys, as those of the Hudson, St. Lawrence and Connecticut rivers. But still we find at all altitudes, evidence of the great southeasterly impulse, which has left its traces over the whole breadth of our continent. Nor have I found any certain evidence, that the striæ existing at the highest altitudes, are older or newer, than those on the lowest levels. It is true that those examples which appear the freshest and most recent, have been at rather low altitude; such as have been brought to light by removing the soil from the rocks. But at high altitudes I have seen no such uncovering of the rocks. I think, also, that the markings on exposed rocks upon the highest mountains are usually less distinct than in the valleys. But it is also true, that exposed rocks are usually more disintegrated and wasted at great heights than in the valleys, because of the greater extremes of temperature prevailing in the higher regions. It should be borne in mind too, that glacio-aqueous agency has transferred bowlders from very low to very high levels; and this was the very agency that smoothed and furrowed the rocks. On all these accounts, I hesitate to say that glacio-aqueous agency took place very much earlier on our mountains than in our valleys. That there was a long interval between its commencement and its close, and that some of its effects were continued in the valleys longer than upon the hills, I shall endeavor to show further on. But after all, I am unable to point out which were the earliest and which were the latest of the striæ, except in a few limited instances: nor can I say which of the bowlders were transported first, and which last; except so far as we can judge from their relative vertical position. The fact is, all the phenomena of drift seem to me in a geological sense to be recent. Our tertiary rocks are strewed over with detritus from all the older formations. Why then must we not infer, that the entire agency has been begun and ended since the deposition of the tertiary rocks? Where is the evidence that it commenced earlier? The direction taken by the bowlders, corresponding with that of the striæ, and the almost equal freshness exhibited by all the phenomena, lead to the conviction that the work was one; and that the period occupied by it was by no means one of the longest of those which geology discloses: though there is evidence that it was much longer than has been usually supposed.

I know of nothing that impresses the mind so much with the recency of glacio-aqueous agency, as a view of a surface of rock smoothed and striated, which has been recently denuded of soil. If other facts justified the conclusion, it would be easy, I think, to satisfy one's self that these markings had been made within the last two hundred years. If any one doubts this, let him compare them with the letters upon the monuments in our churchyards, placed there soon after the settlement of this country; and I am sure he will sometimes find the former the most distinct. And yet, every geologist knows full well that the natural striæ must have been made long before the creation of man.

On the syenite of Rowley, in Massachusetts, I noticed a fact that still more deeply impressed me with the recency of glacio-aqueous agency. The surface was distinctly striated; but on one part it was scaling off to the depth of half an inch, and this obliterated all traces of the striæ. Can it be that many thousand years would be requisite to disintegrate the entire surface of rocks to a depth so small? And yet, wherever covered by soil, the work seems hardly commenced.

It is an interesting inquiry in what mode this smoothing and furrowing of the rocks at all altitudes can have been accomplished. One supposition is, that the present inequalities of surface did not exist when the work was done, and that the mountains have since been elevated. This theory may satisfy the closet geologist, but insuperable objections present themselves to him who carefully examines the localities. He will find that the bowlders are deposited around and upon the mountains, just as they would be, if those mountains existed previous to the distribution of the bowlders; that is, on their northwestern and southeastern sides; and in valleys running in that direction. He will find the tops of the mountains more deeply abraded than their slopes. And what is more decisive, he will find that since the period of glacio-aqueous agency, no vertical movements have taken place, whereby one portion of an abraded and striated surface has been raised one inch above another part. I have never seen such an example. Now, when we recollect that most rocks are full of cracks and fissures, will any one believe that a particular mountain can have been lifted hundreds and thousands of feet without producing any such displacement? The idea is absurd; especially when we recollect the effects often produced by slight earthquakes. And an equally strong argument may be drawn from the undisturbed state of the moraines, frequently found upon the flanks of mountains. Indeed, we may set it down as a settled principle, that *the relative levels of the surface have not been essentially changed since the period of this action.* If vertical movements have taken place, they have affected vast areas, and not particular mountains or districts.

Another theory which suggests itself, supposes that the abrasion of the tops of the mountains took place while the entire continent was beneath the ocean; and that, as it gradually emerged, the sides and bottoms of the valleys were subjected to the same process. I shall consider this general theory more particularly in another place, and shall here merely mention one difficulty in the way of its adoption, that seems to me very strong. After the tops of the mountains had risen above the waters, it is evident that the currents, urging forward the ice that formed the striæ, would now pass around, and not over, the dry land, so that the striæ, except at the very tops of the mountains, ought to pass horizontally along their flanks, and at length become entirely confined to the valleys that now exist. But, as we have already seen, this is not generally the case, certainly not in New England, for the striæ are frequently seen at very low levels, having the same southeasterly direction as on the mountains. It is true that their direction at the tops of our highest peaks, as Mount Washington, Monadnoc, Wachusett, and Mount Everett, differs somewhat from their course at a lower level. But the change, so far as I have noticed, is just the reverse of what, by this theory, we should expect; that is, the course of the striæ at the common levels is more oblique or cross-wise to the mountain ridges than at their top.

The only remaining theory that suggests itself, supposes that the striæ at the lowest as well as at the highest levels, were produced by the same icebergs, which were large enough to reach the bottom of the valleys, and which, notwithstanding, have been urged over the mountains. The latter point appears to present the chief difficulty; for some modern icebergs rise three hundred feet above the sea, and consequently reach to the depth of two thousand four hundred feet; and Capt. Ross saw one stranded in Baffin's Bay, in water one thousand five hundred feet deep. How much deeper may we suppose such an iceberg would reach, as Capt. Parry saw, on which he travelled for some time, supposing it to be fixed, but found afterwards that it was floating him southerly as fast as he advanced northerly?

What proportion of the surface of New England, if swept of soil, would be found thus worn down and striated, it would be presumption to say definitely. But from all that I have seen, for the last fifteen years, I should not be surprised to find one third, or even one half of the surface, exhibiting traces of glacio-aqueous agency.

The direction of the striæ coincides, so far as I know, precisely with that taken by the transported bowlders. And in order to bring at once under the eye the facts on this subject, I have constructed a Map of the north part of America, Plate VII. The red stripes upon it represent the direction of the striæ, as they have been measured in different places; and the green stripes show the course taken by the bowlders. It will be seen, however, that in some parts of the country, there is an apparent disagreement between the green and red stripes. This results from the fact, that observers, in speaking of the direction taken by bowlders, use general terms, such as northerly and northwesterly; whereas the exact course by the compass is usually given when striæ are described. Hence the discrepancy is only apparent. But it is evident that the striæ are most to be relied upon in respect to the course taken by drift. I have given the direction of the bowlders only because it has been described in some parts of the country where no striæ have been noticed.

I have met with one unique case of the abrasion of rocks by the agency which has been described, that ought not to pass unnoticed. In a high bank of gravel, at Fall River, in Massachusetts, or rather just within the limits of Rhode Island, there was uncovered a few years since, the largest bowlder of conglomerate rock that I have ever seen, weighing, as already stated, more than ten millions of pounds. This was transported at least a mile or two, across Taunton river, and driven against a hill of granite. There it lay immovable, and was subsequently worn down several feet, and its surface striated by the continued operation of the same force by which itself was removed. This fact indicates at least the long-continued action of that force.

I have scarcely noticed one variety of effect produced by the abrading agency under consideration, because I intended to describe it as a third class of the phenomena of drift, under the name of

3. Embossed Rocks.

I employ this term as a synonyme of the *Roches moutonnées*, used by Saussure to describe those rocks in the Alps which present a rounded and curled appearance, from the passage over them of glaciers. Upon reading Agassiz' description of these rocks, I became satisfied that they are very common in this country, and that, although they have received a slight notice in the descriptions of the phenomena connected with drift, that importance and prominence have not been given them which they deserve. I am now satisfied that they are a far more permanent memento of glacio-aqueous agency, than striæ; and that often they will enable us to prove that agency when striæ and all other traces have disappeared.

The most striking instance of the embossed rocks which I have met is on Mount Monadnoc, in New Hampshire, to which my attention was called by Mr. Jenkins, of this Association. This mountain is a ridge of mica slate, passing into gneiss, which runs nearly north-northeast and south-southwest; the top of the ridge forming a very gradual slope southwesterly and northeasterly from the summit, which is about three thousand two hundred feet above the sea. The character of the rock and the direction of the range, clearly identify this mountain with the White Mountain system of parallel ridges, although it is one hundred and fifty miles south of the White Hills. The stratification of this mountain is so obscure and irregular, that I do not feel prepared to describe it. Nor is it of much importance in this connection, to notice several dykes of trap and rose quartz, which traverse the ridge in nearly an east and west direction.

I ascended this mountain along its southwesterly slope, and found striæ more or less, from the base to the summit; but they are generally obscure. In the valleys west of the mountain, they run north ten degrees to fifteen degrees west, and south ten degrees to fifteen degrees east, by the magnetic needle; whose variation is eight degrees west. On the top of the mountain they run about north ten degrees west, and south ten degrees east. But along the southwesterly slope, they run nearly northwest and southeast. Hence the glacio-aqueous force appears to have operated in a direction more nearly corresponding to the direction of the mountain at its top and bottom, than on its flanks, — a remarkable fact, which I have noticed in another place.

As one ascends this mountain, he notices an extreme irregularity of the rocky surface. In some places, especially towards the summit, as is common upon most of our high mountains, the frost has broken up and lifted from their original bed, large fragments, which lie in more or less of confusion. But the more common appearance is the rounded and curled rocks, analogous, if I mistake not, to the *roches moutonnées*. I confess, however, that if I had not read Agassiz' description of this phenomenon in the Alps, I should have failed to discover it on this mountain. But when I saw that it is the northwest side of the prominences that are rounded, while the opposite side is angular and jagged; and when I perceived that if troughs occur among the projections, their course corresponds to that of the striæ, I could not doubt but the rounding and the troughs were the result of glacio-aqueous action. In some places the surface much resembles that of the ocean in a storm; that is, with troughs and prominences intermixed: but sometimes, as we look southeasterly, the surface seems embossed more or less regularly, as in Pl. VIII, fig. 3, taken a few hundred feet south of the summit, and embracing a space of about five rods square. The same spot seen from another position, exhibits more of troughs than the figure. Sometimes, as near and a little east of the summit, we see on the southeasterly side of the ledges, a space from which huge blocks, weighing thousands of tons, have been removed by the agency that rounded and furrowed the surface. Upon the whole, though the common marks of glacio-aqueous action are not striking upon this mountain, the embossed rocks are extremely so.

After satisfying myself by repeated observations that the embossed rocks could frequently be discovered where the striæ had been obliterated, it occurred to me that perhaps even the summit of the White Mountains might retain the former appearance, although I had reason to suppose the latter were not to be discovered there. On those mountains, also, if any where in North America, east of the Rocky Mountains, we might expect to find traces of the existence and descent of glaciers in former times. For excepting perhaps a peak in North Carolina, these mountains are the highest land on the eastern side of our continent; and since they are composed of the oldest granite and mica slate, as they were raised from the ocean they would form a centre, or an axis of dispersion, from which glaciers would have carried bowlders outwards, like the Alps in Switzerland, and the Grampians, Ben Nevis, and the mountains of Cumberland and Westmoreland, in Great Britain. On the other hand, could evidence be found on the summit of these mountains that glacio-aqueous agency took a southeasterly course there, it would render it extremely probable that no such centres of dispersion exist in the United States; and that no true glaciers have descended from our mountains. Stimulated by such considerations, I determined last summer (1841) to visit the White Mountains. And allow me here to say, that had no geological discoveries rewarded my journey, I should have been amply compensated by the magnificent and truly Alpine scenery I was there permitted to enjoy.

I approached these mountains from the southeast; following up the valley of Saco river from near the limits of Maine. We enter that valley at Conway, thirty miles distant from the highest summit, called Mount Washington. Its sides are bounded by high mountains, which gradually approach nearer and nearer, till at the Notch, the river, here a mere brook, has cut a gorge of only a few feet wide, through the loftiest ridge of the White Mountains. Along the whole course of the valley, I noticed rather fewer of the phenomena of drift than in most of the mountain valleys of New England. The relics of a few imperfect moraines were all that I saw; and these were much more perfect before I entered the valley. But I shall notice these more fully in another place.

The principal part of the White Mountains, I will not say all, appears to me to consist of steep parallel ridges of granite and mica slate, running about north-northeast and south-southwest, with occasional spurs. The Notch already mentioned, is a passage through the highest of these ridges; and according to Dr. C. T. Jackson, the road at that point is one thousand eight hundred and twenty-nine feet above the ocean. This is the proper place for all visiters, whether they wish to examine the scenery or the geology of the mountain, to stop and accoutre themselves for ascending on horseback to the summit of Washington, which is six or eight miles distant. There is another route, several miles further to the west, which is traversed by many. But they lose the greater part both of the pleasure and the profit of the excursion. Starting from the Notch House, we ascend the first peak upon the lofty ridge; and this has received the name of Mount Clinton; and according to Capt. Partridge, is four thousand six hundred and thirty feet above the ocean. Between this eminence and Mount Washington, the highest point in the range, we pass along the crest of the narrow ridge, and over three other peaks several hundred feet higher than the intervening valleys. The one next to Clinton, is Mount Pleasant; the second, Mount Franklin; the third, Mount Monroe; and beyond Washington, are Mounts Jefferson and Adams. Hence a profile of the whole ridge will present an appearance similar to Pl. VIII, fig. 4. The heights of the several peaks are placed upon the section as determined by Capt. Partridge; though I am not sure that I have put the right numbers upon Clinton and Pleasant.

The top of this ridge is elevated above the region of any vegetation, except some Alpine plants and lichens a few inches high; and on either hand, valleys several thousand feet deep yawn beneath you, while a sea of mountains stretches away on every side as far as vision extends; so that the ride over these peaks, from Clinton to Washington, is romantic and magnificent beyond all conception. The day in which it is performed, if pleasant, will never be forgotten; and in the visions of memory it will ever seem one of the greenest oases that smile along the journey of life.

This ridge is composed essentially of a peculiar kind of mica slate, occasionally containing feldspar, and sometimes traversed by veins of granite. It also abounds, as does the same rock at Monadnoc, with a mineral which has been called fibrolite; but which demands further examination. It often constitutes a large proportion of the rock. All the peaks, except Clinton, which I ascended, (Jefferson and Adams I did not ascend,) are made up of broken fragments of this slate, which have been entirely removed from their original position by frost, and form sometimes a coating of loose angular blocks several feet thick. This is particularly the case upon the summit of Washington, and downward about one thousand feet. But in all the valleys between these peaks, more or less of the rock in place appears; and here I discovered many examples of embossed rocks. They are, as we might expect, much less distinct than in many other places less exposed to decomposing agencies: and I should probably have passed by them without recognition, had I not previously examined many other more distinct examples. Any one who will do this, will be satisfied that the same phenomenon is before him upon the White Mountains. So far as Mount Clinton has been uncovered, it seems one huge boss, more or less rounded. In the valley between this peak and Mount Pleasant, or rather as we begin to ascend the latter, the embossed rocks are quite distinct; and here too are bowlders, most evidently transported, though being of primary rocks, their lithological characters do not determine the place of their origin. Here too, I discovered striæ running north thirty degrees west, and south thirty degrees east, corresponding essentially with the general course of striæ on the mountains of New Hampshire and Massachusetts. I did not notice these striæ on ascending the mountain in the forenoon; but they were distinctly visible when the sun was low in the west. Mrs. Hitchcock, who accompanied me in this excursion, took a sketch of the embossed rocks at this place, which is not given here, lest the drawings of this paper should be too much multiplied.

Near the south foot of Mount Franklin, that is, in the valley between Mount Pleasant and Franklin, is another example of the embossed rocks with bowlders; a sketch of which is given on Pl. VIII, figure 5.

Finally, at the south foot of Mount Washington, near a small pond called the *Lake of the Clouds*, is a third example of the *Roches moutonnées.* It is less distinct than at the other localities, as the rock here is more broken up by frost; still, it is impossible for a practiced eye not to recognize them. And it ought to be stated that here, as at all the other places mentioned above, it is the northwest exposure of the rocks that have been most powerfully acted upon; proving conclusively that the force was exerted from that direction.

Capt. Partridge states the Lake of the Clouds to be five thousand feet above the ocean: consequently it is about one thousand two hundred feet below the summit of Washington. But can there be any reasonable doubt that the rocks on the summits of all these peaks were once abraded by the same agency, and that, were they in place, they would still exhibit traces of it? Certainly, it appears to have acted powerfully at the height of five thousand feet; the highest point yet discovered in our country where it has acted. And it seems to me that the facts detailed lead to the following important conclusions.

In the first place, the same glacio-aqueous agency that has operated in a southeasterly direction over the northern parts of this continent, at the lowest and at intermediary levels, has acted in the same manner, and in the same direction, upon the summits of the White Mountains.

Hence, secondly, that the same force surmounted all the mountains on this continent east of the Mississippi.

Hence, thirdly, we have no reason to suppose that the White Mountains have ever been a centre from which bowlders have been dispersed; and no evidence has been discovered on the sides of the mountain of the former existence of glaciers, other than icebergs floated by a current.

Hence, fourthly, the presumption is strong, that no other mountains east of the Mississippi have been centres of dispersion, or have been occupied by *Mers de Glace*, emitting glaciers. For the high latitude of the White Mountains makes it more probable that glaciers should have existed there than on any other of our mountains, except those of Essex county in New York; and Professor Emmons, in his Reports, represents the force there as acting in a southerly direction. And since we are sure that the same southeasterly impulse, connected evidently with currents of water, which has produced the phenomena of drift at lower levels, has operated in one place to the height of five thousand feet, it furnishes an adequate cause for the like effects at the same height all over the continent; and, therefore, to call in the aid of other causes, is unphilosophical. To stand at that dizzy height, and witness the erosions of this agency, makes a deep impression of its potency and far-reaching influence; especially if we suppose aqueous currents ever to have attained such an altitude; or of its immense antiquity, if it acted when these primeval mountains were at the bottom of the sea.*

* *January* 1, 1843. "Mountains of considerable elevation in Scotland,— Schihallion for example,— have their summits as polished as their flanks; whereas in Switzerland there exists a limit, at about nine thousand French feet in the centre of the Alps, above which the summits are no longer polished; but where the rugged peaks present a very striking contrast to the lower surfaces, which are polished, or at least *moutonnées*. In the interior chains of the Alps, the polishing does not reach to a greater height than six thousand or seven thousand feet." — *Agassiz on the Glacial Theory, New Ed. Philos. Journal, Oct.* 1842, *p.* 232.

I do not mean to assert in the preceding inferences, that the drift has taken a southerly direction from the very pole. In advancing northerly through Canada, the point may yet be reached, as perhaps it has been in northern Europe, where this direction will be found reversed. Still the great height at which the surface has been eroded on the White Mountains, makes it probable that such a point, or axis of dispersion, if it exist, must lie very far to the north; certainly if, as analogous examples would lead us to suppose, that axis be more elevated than any other regions over which drift has been carried. No such lofty mountains, I believe, have yet been discovered in the northern part of this continent. They certainly must lie north of Hudson's Bay, if they exist.

4. Valleys of Erosion.

It has always been a difficult matter to determine what valleys have been due wholly or in part to glacio-aqueous agency. A single example of this kind must stand *instar omnium.* Indeed I have never met with another well marked case in our country. The case referred to, is upon Mounts Holyoke and Tom, in the valley of Connecticut river. These mountains constitute about fifteen miles of the northern extremity of a narrow trap ridge, commencing at New-Haven and extending to Belchertown. All that part east of Connecticut river is called Holyoke, while Tom lies on the other side. The highest points rise above the river, between eight hundred and a thousand feet, and the western and northern side is very precipitous, except near the bottom, where the sandstone crops out beneath the trap. The ridge lies in a curvilinear direction, between the towns of East Hampton and Northampton, Hadley and South Hadley, Amherst and Granby, as shown on Pl. VIII, f. 6, in such a manner that several miles of its eastern part runs nearly east and west; but its southern part, nearly north and south. Its top is usually only a few rods wide; and on its southern and eastern side, it slopes rather gradually.

Now as one approaches this ridge from the north, say through Amherst, he will see its top to be irregularly serrated, as shown on Plate VI, of my final Report on the Geology of Massachusetts.

This appearance results from a great number of valleys of various depths, running very nearly north and south, and almost exactly parallel to one another. Of course, where the mountain runs nearly east and west, these valleys will cross it at right angles. I formerly supposed these valleys to be the result of the original structure, or mode of elevation, of the mountain. But discovering striæ and broad grooves on the top of the ridge, especially along its northern edge, I was led to inquire whether the valleys also might not have been the result of glacio-aqueous agency: and it occurred to me, that if they were, they would not cross the ridge at right angles, as it curved so as to run almost north and south; but would retain their parallel, that is, nearly north and south direction: whereas, if the result of original structure, or elevation, they would probably cross the ridge at right angles on all parts. An excursion along the top satisfied me that they preserve their parallelism in a most remarkable manner; and that the slight deviations from it, where the valleys run in nearly the same direction as the ridge, are such as to confirm, instead of invalidating, the supposition of their glacio-aqueous origin. We there sometimes find a narrow ridge, terminating on the north in a bold but rounded front, which appears as if it had been powerfully acted upon by a force which was not sufficient to remove it, and was, therefore, obliged to urge its way on either side, so as to form two narrow valleys a little diverging from the main one. The northern extremity of some of these bluffs of trap is arranged somewhat like steps, and reminds one of Berzelius's description of the northern extremities of mountains in Sweden, which resemble sacks of wool piled one upon another.

The depth of these valleys varies from a few feet to several hundred. Through one of them Connecticut river passes; and its bed is more than eight hundred feet below the ridges that rise on either bank very precipitously, and exhibit striæ and rounding from top to bottom. But I have ascertained that this gorge was in part produced by a fault running across the sandstone in this place, whereby it suffered a depression where the river runs; so that we cannot suppose that glacio-aqueous action wore down this passage from the top of the mountain. And so in respect to several others of the deeper valleys, they may have existed previous to the exertion of this force; and yet, where we find a valley running obliquely across the ridge, it is difficult to impute its commencement to any other agency. Is it not perfectly obvious, also, that currents of water never could have begun such valleys? For instead of ploughing their way obliquely along the sloping edges of an excessively hard rock, they would have been turned along its sides. But suppose a mass of ice, wide enough to fill the valley of the Connecticut, to be urged over the top of this mountain, with bowlders frozen into its under surface. The consequence would be, since these gravers could not be crowded either to the right or the left, that they would cut their paths along whatever surface they were urged over. Parallel furrows being thus begun, the currents of water would be diverted into them, bringing along perhaps smaller fragments of ice, and thus would they be deepened in the course of centuries, as the mountain continued to rise, or the water to fall. Nor would the work cease until the present configuration of the surface had been produced. I confess I can conceive of no other mode in which the erosions on this mountain can be explained; and although not entirely free from difficulties, this theory carries with it an air of probability. I can conceive no reason why such examples are not common, except that in few places would glacio-aqueous currents continue to operate so long as in this valley, and few mountains are so favorably situated for receiving and retaining the evidence of their action. I regard this case as affording very conclusive evidence, first, of the great length of the glacio-aqueous period; and secondly, of the insensible manner in which glacio-aqueous passed into alluvial agency. I do not mean that this period was long, compared with many others which geology reveals. But we have proofs here beyond all question, that glacio-aqueous action could not have been the result of any transient overflow of water and ice; and that centuries at least must have been occupied in such erosions.

5. Moraines.

If the term *moraine* must be limited to those accumulations of detritus which are produced by glaciers descending from mountains, then it seems to me, that we have yet no evidence of the existence of moraines in this country, except along the northern ocean. But if we may embrace in the term those masses of drift that have been produced by the stranding of icebergs, and by their grating along the bottom, and perhaps by their gyratory motion, then, if I mistake not, our country abounds with moraines. I shall venture to use the term with this extended signification, in describing our drift. All the ridges and hills of gravel which I call moraines, are evidently *iceberg moraines.*

The definition which I should give of an American moraine is this: — a mass of detritus, more or less worn, that has been transported, or crowded along, and piled up by drift ice. Such a mode of formation would of course generally obliterate the marks of stratification, if they ever existed in the transported mass. But as water must have been concerned in crowding along the ice, we might expect that its currents would sometimes act on the finer part of the materials, and produce, it might be, lamination and stratification in one part of a moraine, while the greater part of it was destitute of parallel arrangement. Again, the drift ice might sometimes crowd along a previously stratified deposit to a considerable distance, without destroying entirely the bedding and lamination. Now the fact is, that what I call moraines, correspond to these suppositions. The most remarkable of them are entirely unstratified. In others we see occasional traces of a sorting and parallel arrangement of the ingredients, strangely mixed up with the unarranged mass. This fact always appeared to me entirely inexplicable, till the joint action of ice and water was suggested as the cause. There are other cases, in which I suspect that a deposit of laminated clay was crowded along, *en masse*, and left in the midst of rounded and unstratified materials. As an example, I would refer to Pl. VIII, f. 7, representing the north bank of a deep excavation on the rail-road in Palmer, in Massachusetts. Its length is about twenty rods; and its height, in some places, as much as fifty feet. The bank is mostly composed of unstratified drift, from minute pebbles and sand, to bowlders several feet in diameter. In the midst of the drift, occur at least two quite large deposits of fine clay. The coarse drift also, on the right, is stratified with a dip not less than twenty-five degrees. The upper bed of clay terminates abruptly on the right, and is somewhat disturbed. It is possible that it may have been deposited in the spot it now occupies: though in that case it must have been by the agency of gentle currents of water, acting on the drift that had been crowded along by the ice: but it seems more probable, that the clay is a portion of some larger deposit, which was broken up and removed without obliterating its lamination.

Moraines constitute the great body of drift; forming ridges and hills sometimes, though rarely, two hundred or three hundred feet high. The materials are much more comminuted, and the pebbles and bowlders more rounded, than the more scattered drift. The most usual composition of these moraines is perfectly rounded pebbles and coarse sand. In a few instances, and those very remarkable, they consist entirely of sand. Large bowlders, also, sometimes constitute a considerable part of the mass. But in all cases there is evidence that the materials have been subject to a powerful mechanical agency.

Our moraines form ridges and hills of almost every possible shape. It is not common to find straight ridges for a considerable distance. But the most common and most remarkable aspect assumed by these elevations, is that of a collection of tortuous ridges, and rounded and even conical hills, with correspondent depressions between them. These depressions do not form valleys, which might have been produced by running water; but mere holes, not unfrequently occupied by a pond. These ridges and piles form a very curious landscape, and yet not strange to an inhabitant of New-England.

Pl. VIII, fig. 8, represents a remarkable example of these moraines, in the town of Truro, near the extremity of Cape Cod. The hills there are composed entirely of sand, and some of them are one hundred or two hundred feet high. Several square miles near the harbor in that town exhibit a similar aspect.

To whatever cause any one may impute such singular elevations and cavities, he will not doubt, as he looks at them, that they have now almost precisely the contour which they assumed at their origin. And it seems to me, that every reflecting mind will be still more confident, that mere currents of water never could have piled up sand and gravel in this fantastic manner, especially on so gigantic a scale. What current of water could scoop out holes, sometimes one hundred or two hundred feet deep ? It is difficult enough to conceive how running water could pile up a ridge of gravel, twenty or thirty feet high, with a steep slope on each side: but here we have an effect vastly more difficult to explain by such an agency. Yet let us imagine a large body of field ice, with its under surface very irregular, and that this, by the force of currents, has crowded along the sand and gravel, so that they occupy its cavities, or are borne along upon its top. It is easy to conceive, that in this way, precisely such a singular configuration of the surface, as has been described, might be produced: and when the ice melted away, the irregularities would remain as we find them.

The peculiar moraines that have been described, are very common all over the northern parts of our country; although not always large enough, or they are too much concealed by vegetation, to be very striking. The latter is the case at Mount Auburn, in Cambridge, which owes its romantic inequalities to this latter cause. I have pointed out many localities in Massachusetts in my Final Report on the Geology of that State. And I am sure that they occur also in the other New-England States, as well as in New York, Michigan, &c. As one passes along the Western Rail-Road from Albany to Buffalo, he sees these moraines occasionally; probably, however, less numerous and distinct than in the more hilly region of New England. I noticed them in great numbers a little west of Auburn; particularly in the town of Victor, where they skirt the rail-road for several miles. But the best example which I saw in New York, is at Mount Hope, two miles south of Rochester, which is a cemetery for the city, rendered very romantic by these peculiar moraines, which are larger and more striking than at Mount Auburn. One cavity here is some sixty or seventy feet deep, with very steep sides, and nearly circular. I observed that this group of moraines extends a mile or two east of the cemetery. These hills cannot be far from the remarkable smoothed surfaces of limestone, so well described by Professor Dewey, in the vicinity of Rochester. No doubt the two phenomena are connected.

The southeastern part of Massachusetts exhibits the most remarkable examples of these tortuous and conical moraines which I have seen. They extend along the sea-coast from Kingston to Falmouth, nearly fifty miles. And really they are of mountainous size; sometimes two hundred, or even three hundred (Monomet Hill in Plymouth) feet high. Standing upon one of these hills, the surface appears like that of the ocean just after a storm. The drift is composed here of enormous bowlders, pebbles and sand; and the bowlders are often of such size and in such numbers, as to give the impression to the most practiced eye, of large naked ledges *in situ.* No ledges, however, appear in that region; and excepting the moraines, the country is but little uneven.

Another remarkable example has been already referred to, near the eastern extremity of Cape Cod. Its situation is on the coast, with no high land near. These moraines are the only ones I have seen entirely composed of sand, (except perhaps between Albany and Schenectady) and yet they yield to none in size in New England, except perhaps some of those already described on the west side of Massachusetts Bay.

I have mentioned these two cases, chiefly on account of their important bearing upon the theory of the origin of moraines. In these instances we find them of greater size than any where else; and yet situated, one set of them fifty, and the other one hundred miles distant from any mountain much higher than themselves, and more than two hundred miles distant from any mountain that could ever have sent out glaciers. The conclusion seems irresistible, that they could not have been produced by ordinary glaciers, descending the slopes of mountains by expansion. But if produced by enormous icebergs, it is as easy to conceive of the stranding of these along the low region of Cape Cod, as upon our mountains.

I think, however, it is generally true, that these moraines are most common in mountainous districts; or rather, about midway between the highest and lowest levels. The valleys of existing rivers and the vicinity of gorges in mountains, most abound with the detritus under consideration. The moraines more usually preserve their original form near gorges no longer occupied by currents: as our rivers have generally modified their form, in a mode to be hereafter described. And I doubt not, that as the waters retired, either by subsidence, or the rise of the land, large quantities of ice would be urged by the rivers along their channels, acting somewhat in the manner of descending glaciers; that is, forming lateral moraines, and terminal too, where the hills closed in upon the river so as to stop the ice.

It may be suggested that all our moraines were produced in the manner just pointed out; and had no connection with that southeasterly impulse, which scattered the bowlders. But this idea is opposed by several facts. And first, the smaller detritus of moraines, so far as I have observed, had the same northern origin as the bowlders; although the moraines are rarely carried as far as many of the blocks. Secondly, the western slopes of mountains, running nearly north and south, abound far more with these moraines than the eastern slope; as if all the detritus accumulated on the eastern slope, were driven southeasterly across the valley, until obstructed by its eastern side. Thus, in the valley of the Connecticut, we find very few striking examples of these moraines along its west side, or in the valleys of the rivers that descend the eastern slope of Hoosac mountain into that valley. But along its eastern side, and for a considerable distance up the primary hills that form its eastern boundary, they abound every where, and are often most striking. So along the eastern side of the Taconic ridge of mountains, we see but little drift. Yet along the base, and extending up the valleys for some distance on the western side of the Hoosac range, that runs parallel to the Taconic, and bounds the valleys of Berkshire on the east, moraines are very abundant. So that while we find evidence that detritus has been driven down the valleys occupied by rivers, we find, also, that as a whole, it has obeyed that force which has carried our drift southeasterly. It would not be strange, if some cases should be found, where the force urging it along particular valleys should have carried it in almost an opposite direction: though I have never met with such a case, and presume, if it occur, it is probably quite limited.

Since printing my Report on the Geology of Massachusetts, I have met with a few examples of the peculiar moraines above described, in the eastern part of that State, which deserve a short notice.

The town of Newburyport appears to be built entirely upon a ridge of drift, which has been more or less modified. High Street runs along the highest part of the ridge; and if we proceed westerly, we shall follow the ridge for three or four miles. At that distance * we meet with a good example of those peculiar tortuous ridges, and irregular tumuli with deep depressions, which have been described. In the depressions I noticed one or two ponds. A few of the same ridges and tumuli occur within and around the cemetery at the head of High Street in Newburyport. The cemetery occupies a tumulus, as is the case at Plymouth, North Adams, and some other places in Massachusetts. A pond also occupies a depression at the head of High Street. It ought likewise to be mentioned, that the materials of the moraines in the town, are considerably coarser than those three miles west, where they are chiefly coarse sand.

I was conducted to another spot where these peculiar moraines occur, by Dr. Robinson of Salem. It lies three miles southeast of that city, on the road to Marblehead, and just within the limits of the latter place, as we rise a high rocky hill. Against that hill, a few rods to the west of the road, and in a spot where we should hardly look for them, we find several of these moraines, with very steep sides and deep cavities between them. A pond occupies one of the depressions. The drift here is composed mostly of gravel; although rather more coated with grass than is usual.

* I am indebted to Mr. Anthony Jones, of Newburyport, for conducting me to that spot.

There is one very curious variety of the moraines that have been described, which I have not noticed above, because I suspect they have been modified since their formation, by alluvial agency. They are merely insulated conical tumuli of gravel, sand, and bowlders, usually occurring at the foot of mountains. Hence it is probable that they are the remains of detritus, which has been more or less worn away by streams descending from the hills. I do not feel fully satisfied with this theory; first, because it is difficult to conceive how such perfect tumuli should be thus produced, some of them nearly one hundred feet high: secondly, because some of them occur at a distance from any mountain. Still, I cannot conceive how they should be produced in any other way; unless possibly by being conveyed upon the tops of icebergs, which melting, left them of a conical shape. So artificial is their appearance often, that they have in various countries been regarded as artificial. Professor Struder lately described some of these in Berne, in Switzerland, which "were there universally supposed to be the works of art:" but on excavating them, they were found to consist of Alpine bowlders and gravel. Probably many of the mounds in our western States, now regarded as the works of man, will be found to have had a similar origin; or to be the remains of alluvial deposits, worn into various shapes by water, upon which man has erected fortifications and other structures.*

The deep valleys of Berkshire county, in Massachusetts, pre-

* I have several times advanced this opinion in my publications upon geology; and as I expected, it has met with strong opposition and ridicule from writers of almost every grade. But the more I learn concerning these mounds, and concerning similar tumuli on the eastern continent, the more convinced am I, that many of them, I mean the larger ones, are more indebted to nature than to art. I wish to be distinctly understood as admitting the existence of artificial mounds and ridges in our western States, as well as in the eastern world. But I maintain, that in many cases, man, instead of piling up with vast labor these mounds and ridges, has chosen those already prepared for him by nature, as convenient spots on which to erect fortifications and other structures. If these larger mounds shall be cut through, and the materials be found not sorted or stratified, but evidently of artificial origin, ridicule will be found a much more powerful weapon with which to combat my opinion, than it now is. *Nous verrons.*

In support of my views I would refer to Professor VANUXEM's Report on the Geology of New York, p. 247, and to Rev. S. Parker's Exploring Tour beyond the Rocky Mountains, third edition, p. 39.

sent some of the most remarkable examples of these moraines. In North Adams, which lies in a deep and narrow trough between mountains two thousand or three thousand feet high, we find most striking exhibitions. About fourteen of these tumuli, some of them nearly one hundred feet high, are ranged in a line on the eastern side of the valley, which are represented, though imperfectly, in Pl. VIII, fig. 9. Half a mile further north, others give the landscape a unique appearance, as is represented in Plate 3, of my Final Report. That Report contains a sketch of others in the south part of Berkshire county, at the foot of Monument Mountain.

I have already alluded to the rarity of moraines which are nearly straight ridges. Often such ridges are found connected with the irregular and conical moraines that have been described: but they are usually short. Sometimes, also, I have seen gravel ridges extending partly across a valley through which a river runs, which I suspect once constituted a terminal moraine, (that is, of ice urged forward by water,) through which the river has cut a passage. We frequently also, find banks of gravel along our rivers; which, however, show a talus only towards the river. I cannot doubt that these were once lateral moraines, and that the talus on the side next the bank, has been concealed by the detritus which has slid from the bank. Indeed, where lateral moraines are produced, as I suppose these were, by ice driven forward by water, we ought not to expect to find as distinct ridges of any kind as those produced by glaciers; because the water, especially if deep, would do much to modify them and fill up inequalities. I have, however, met with a few insulated ridges of gravel which still retain both their slopes, though they appear more commonly to be the mere wrecks of moraines.

The broad ridge of gravel extending through the town of Amherst, in Massachusetts, from Mount Holyoke, six or eight miles northerly, appears to me to be a case of this kind, though subsequently a good deal modified. It seems to have been produced mainly by the ice moving down the valley of the Connecticut; such decided marks of which, I have described as occurring upon Holyoke.

I have alluded to a few moraines, which I met in my excursion to the White Mountains; but they were not at all remarkable on the route which I took. The irregular and tortuous ones are somewhat common along the western shore of lake Winnipiseogee. But still better examples may be seen in the pine woods on the west shore of lake Ossipee. Some of these are ridges of considerable length: but they are not near any high mountain. Two or three miles southwest from Adams' tavern in Conway, on the road to Eaton, and in a narrow valley between high hills, are some rather remarkable moraines, which need more examination than I was able to give them. The principal moraine is a ridge running lengthwise of the valley, and half a mile long. It appeared to me, in passing it, to be nearly straight. Near its north end is a deep pond.

The valley of Saco river, between Conway and the Notch, a distance of thirty miles, presents fewer examples of moraines than is usual in a mountain stream: though beds of detritus with steep slopes, do sometimes occur. And in passing from the Notch westward towards Connecticut river, we meet with few traces of moraines. At the distance of five miles from the Notch, however, and a few rods before we reach Fabyan's tavern, I noticed the remnant of a rather remarkable ridge of gravel, which has been dug away at one end for a road. The sketch, Pl. VIII, fig. 10, will give some idea of its appearance as we approach Fabyan's. It lies on the north side of a wide valley, running longitudinally, and seems to be the fragment of a lateral moraine. It is about twenty feet high and several rods long.

I followed the valley above-named fourteen miles from the Notch House, yet saw no other marks of glacial action. But upon the Ammonoosuc, below the village of Lisbon, I noticed several ridges of gravel and sand, strongly resembling moraines: one of them appeared like that above sketched, though larger: others seemed to have been terminal, and cut through by the river.

But of moraines in ridges, decidedly the most interesting and instructive case which I have met with, occurs in Andover, in Massachusetts. That region is primary, and somewhat uneven;

but the hills are low, rarely more than one hundred or two hundred feet high, and the slopes very gradual. The village in Andover, around the Theological Seminary, stands upon one of these broad swells of land; and about half a mile west of the seminary, a small stream, two or three rods wide, called the Shawsheen, runs northerly towards the Merrimack. On each side of this stream, the land rises very gently for some hundreds of rods. And it is upon the west side of the river that these remarkable ridges occur. They all consist of long narrow ridges of gravel, or sand, having a nearly equal slope upon each side. One of them is well known in Andover, under the name of *Indian Ridge;* and being for a considerable distance covered with pines, it forms a romantic path for literary peripatetics. In company with Rev. Alonzo Gray, of Andover, I traced this ridge towards a mile and a half, interrupted only occasionally by a road, or a brook, or other slight depression. This ridge is shown on the Map of Moraines in Andover, Pl. IX, extending from A to B. When we examined it, we supposed, that after a considerable interruption between B and O, it continued to F, where it was covered by a deposit of sand, forming a sandy plain. But subsequent examination has satisfied Mr. Gray, that this western part of the ridge (O F,) continues southerly as far as E; and in general, he says that this Western Ridge is on an average fifteen feet higher than Indian Ridge, though of the same general character. He has also traced an East Ridge, branching off from the Indian Ridge at C, and running northerly to D, one hundred and eighty-five rods. These three ridges he has taken the pains to survey with a chain and compass; and from his minutes they are laid down on the accompanying map. The ridges represented at G, H, L, M, and N, are placed upon the map without being surveyed; and they merely indicate that moraines of some extent exist there, and possibly they may have some connection with the three ridges above described. But until they shall have been surveyed and placed in their exact position upon the map, it will be unsafe to found any inferences upon them. They were not surveyed for want of time.

The height of Indian Ridge above Shawsheen river, varies from sixty-eight to eighty-six feet; and its elevation above the adjacent surface, is from fifteen to thirty feet. Its breadth is not usually more than four or five rods through the base; though this last statement is not the result of actual measurement. On the top it is frequently only wide enough for a good road. The height of the East Ridge is not given in Mr. Gray's notes, though I am confident it cannot be quite as high as the Indian Ridge. The shape of these ridges, through a considerable part of their course, is almost a semi-cylinder; though usually somewhat flattened, especially where the ridges interfere with one another. The length of the East Ridge is one hundred and eighty-five rods: of Indian Ridge, four hundred and twenty-three rods, or one mile and one third: of West Ridge, five hundred and fifty-nine rods, or one mile and three quarters.

Now what explanation shall we give of the origin of these extraordinary ridges? It seems to me hardly possible that any one should examine them and not be satisfied that they must have been the result of some other mechanical agency besides, or in addition to, that of water. If we suppose large and successive masses of ice to have been forced over the spot, filling up more or less the valley of the Shawsheen, the lateral moraines which they would pile up, would correspond exactly almost to these ridges. The great irregularity of the rocky sides of the valley, would force the mass of ice more or less out of its direct course, to the right and the left, so as to account for the serpentine direction of the ridges. Successive icebergs, also, would often disturb the moraines produced by those which had gone before, and sometimes perhaps move the previous ones out of their place, making to them the addition of a new moraine; as seems to have been done between A and C, by the agent that formed the ridge C D. A similar interference may be seen in several other places. If we suppose the West Ridge to have been produced at first by a mass of ice, wide enough to fill the whole valley, the Indian Ridge may have been subsequently formed by a smaller mass, and the East Ridge by one still smaller.

In still further confirmation of these views, it may be stated, that the general course of these ridges corresponds very closely with the direction of the striæ upon the rocks in Andover, which is nearly north and south. The idea of glaciers, however, occuring in this almost level region, and removed one hundred and fifty miles from any mountains whence glaciers might have descended, appears to me absurd: and hence the work must have been accomplished by icebergs.

It might be supposed, perhaps, that these ridges were produced as ridges of sand and gravel sometimes are, along the sea coast and near the shores of lakes, by the action of waves and currents, when the region was under water. But in the first place, they are much steeper and narrower than any such ridges now forming. Indeed, we cannot conceive how it is possible for water alone to pile up such ridges. In the second place, no lake or other expansion of water could have existed in this valley, wide enough to allow its waves to produce such an effect; as in order to do it, they must have moved either from the east or the west, and the ridges are but a short distance from what must have been shores in such a case. Finally, the materials of these ridges were brought mostly from the north; and waves, or a stream, moving southerly, through a passage not wider than a large river, could not have produced high longitudinal ridges. These difficulties will strike a person more forcibly who examines the spot, than when stated in language.

I presume that still further careful examination of the region above described, may show other similar ridges, or a continuation of those on the map. Indeed, remnants of them are discoverable further south; but it was thought best not to represent them. At their northern extremity, a deposit of coarse sand appears to have been subsequently brought in by water, which has covered them up. A mile or two south of their southern extremity, moraines abound, which have not yet been examined with reference to the existence of continued ridges. In company with Mr. Gray, I visited South Reading; where, at the northern extremity of a valley, and a few rods east of the village and a pond, is a very interesting ridge, nearly half a mile long, of the same general character as those in Andover. It is quite serpentine; and on its east side especially, quite steep. In some places, also, it is higher than those in Andover. I had intended to obtain a drawing of it; but could not survey it. I would gladly re-survey all the moraines with which I am acquainted; in the confident belief that, now *I have been learnt to see*, as Dr. Macculloch expresses it, I should find many of these continuous ridges, where I have supposed only a confused group of moraines to exist.

In a recent rapid excursion through the State of New York, I noticed, if I do not mistake, a few examples of moraines in ridges, which I will briefly mention. As one passes by rail-road over the dreary sandy plain between Albany and Schenectady, he sees many examples of moraines, and several long and high ridges, running, if I mistake not, nearly in the direction taken by drift in that region. I can hardly doubt that these are of the same nature as those in Andover; and they deserve a careful examination.

A little north of the town of Syracuse is a high ridge of gravel, or rather two ridges, running a little west of north, and east of south, and corresponding, as I am informed, to the course taken by drift in that vicinity. At their base I noticed some large bowlders of primary rocks from Canada; as indeed one does, all the way from Little Falls to Buffalo. Such ridges, I am told, are not unfrequent in central and western New York; and where they coincide in direction with the striæ on the rocks, we may infer that they are linear moraines.

I can hardly doubt that the linear moraines of this country are of the same character as the *Osars* of Sweden, described by Brongniart, Beaumont, Durocher, and others. Yet I have seen no account of these osars, sufficiently minute, to enable me to judge whether they are so narrow, so steep on their sides, and so crowded together as to interfere with one another, as we find to be the case in our linear moraines.*

The comparative recency of the agency by which the moraines above described were produced, has been strongly impressed upon

* *January* 1, 1843. In Mr. DARWIN's paper on the *Ancient Glaciers of Caernarvonshire*, in the New Ed. Phil. Jour. for Oct. 1842, is a description of moraines in that country, corresponding almost exactly to those in Andover and South Reading. " They " (mounds of gravel,) says he, " at first appear quite irregularly grouped : but to a person ascending any one of those farthest from the precipice, they are at once seen to fall into three (with traces of a fourth) narrow, straight, linear ridges "—p. 353.

my mind by an examination of their outlines. When they are composed of sand and gravel, and have steep sides, it seems impossible that every powerful rain should not wash away some portion of them and convey it to the bottom. Yet it is rare to see in the cavities between them much accumulation of alluvial matter. A random estimate would imagine a greater change of this sort in a few centuries, than has actually taken place in the thousands of years that must have passed since the moraines were piled up.

Another inference of importance has been forced upon me from the same facts. When I see these moraines around the base, and on the flanks of mountains, retaining the very shapes which they took when first produced, I cannot believe that those mountains have been elevated since that time. If they had been, how is it possible that loose and steep hills of gravel, should not have been disturbed and crumbled down, as they have been by the uplifting of the Alps? If the northern part of our country, therefore, has experienced vertical movements since the glacio-aqueous epoch, it must have been as a whole: for local elevations to much extent are out of the question.

It is only recently that moraines have been described by geologists as a part of the phenomena of drift. Nine years ago, I described those of Massachusetts in that connection, and gave sketches of some of the most remarkable cases in my Report on the Geology of that State, published in 1833. But as I saw in the writings of European geologists only slight notices of such phenomena, I feared that I had mistaken their character, until the papers of Agassiz, Buckland, and Lyell, were read before the London Geological Society, on the marks of glacial action in the north of England and in Scotland. I then perceived that these appearances were precisely the same on both sides of the Atlantic: and the introduction of the agency of ice into geological dynamics, is beginning to throw light into this hitherto dark and untrodden field.

6. Detritus of Moraines.

If currents of water were concerned in the production of moraines, as we have supposed, we should presume, that as the ice melted away, those currents would often change their direction, so as to wear away the moraines, and deposit their ruins in other places. Of course these new deposits would be stratified; because the materials would be sorted by the water. And as the minor currents would be much deflected among masses of ice and irregular hills, we might expect cross and contrary currents, producing irregular and inclined lamination. Accordingly we find that much of that detritus which we must refer to glacio-aqueous agency, originally, exhibits such stratification and lamination as have been described. And such re-arranged materials have been appropriately called the *Detritus of Moraines.* A section of such moraines will give a perfect idea of them. Plate VIII, fig. 11, shows one in the town of Uxbridge, two miles south of the principal village, on the road to Providence. It is five rods long, and eight or ten feet high. The materials vary from coarse gravel to common sand.

7. Deposits of Clay and Sand.

If drift was borne and driven along by masses of ice, as we have supposed, we should expect to find it accumulated in the vicinity of narrow gorges: and there in fact we do find it, blocking up the passage frequently, unless a river pass through the defile. In that case we find the drift cut through to a great depth. Now this excavation must have been a slow process; and when it commenced, the stream must have been so much higher than at present, as to throw back the waters where level regions existed: in other words, numerous lakes and ponds would be formed at the close of the drift period: and as we suppose the ice, whether transported or accumulated on the surface, to continue for a long time to melt, the streams thus produced would carry large quantities of mud and sand into the basins above described, where they would be deposited in the most quiet manner, in horizontal or slightly inclined layers. Such seems to have been the origin of those deposits of stratified clay and sand, that occur in almost every basin of much size in the northern parts of this country. The clay is blue, and the iron in it, which amounts to nearly ten per centum, is usually in the state of protoxide. Its beds vary in thickness from a very few feet up to one hundred; and the laminæ are rarely more than half an inch thick. The sand almost invariably lies above the clay, and is rarely more than fifteen to twenty feet thick. At the upper part of the clay bed, we find occasionally alternations of layers of fine sand; but usually the transition from clay to sand is quite rapid, and accomplished in a vertical direction of a few feet, or more frequently of a few inches.

It is rare to find alluvial deposits overlying the sand above described as belonging to the drift period: for the alluvium seems generally the result of the wearing away of the sand and clay, though we frequently find clay beneath what we know to be an alluvial deposit. I am not aware that our rivers at present deposit proper clay; certainly not that blue clay which underlies the sand. Neither is the alluvial deposit commonly of coarse sand, but rather of fine sand; forming a sort of loam, often containing considerable organic matter. Indeed, our alluvial deposits contain organic remains, both vegetable and animal: but those connected with drift, very rarely contain them. And I hardly know of a better distinction between the sand and clay of drift and alluvial deposits, than to draw the line where we find the organic relics begin. For these seem to mark a change in the state of the surface, and the waters, favorable to organic existence. It is evident, however, that as the barriers of detritus gradually wore away, the lakes and ponds would be reduced in size; but depositions would continually go on, until the present state of the surface was attained. Perhaps it would be better to consider the alluvial period as commencing with the deposition of the lowest beds of clay. We should then have a clear lithological distinction between drift and alluvium. But on the other hand, the clay and sand were evidently deposited previous to the last creation of animals and plants on the globe; since none of them are found in this formation; and, therefore, the period of its deposition seems more properly to belong to the glacial period of drift, than to the sunny days of alluvium. Whether the deposit exhibited in Pl. VIII, Fig. 12, was formed before, or since, the commencement of the historic period, I am unable to decide: but am inclined to place it a little anterior to the latter. It occurs in a deposit of fine gravel, sand, and loam, lying immediately above the clay, in the south part of Northfield, in Massachusetts, on the stage road, near Connecticut river. I give it chiefly as affording a fine example of cross and inclined stratification in fine materials. It is only a few rods in length.

The occurrence of sand above the clay, in the formation under consideration, is a fact to my mind very perplexing. I do not see why it does not indicate a greater violence in the waters which brought the deposits into the lakes and ponds, than when the clay was in a course of deposition. Yet the occurrence of the sand above the clay is no local fact, but is common all over the country where the two deposits exist. Some general cause, therefore, must be assigned for it. It is clear that rivers, in their present state, bring down materials intermediate as to fineness between the sand and the clay of the drift deposit. It is well known that the mud produced by the grating of ice along the surface, is finer than can be formed in almost any other way. Such mud would of course be the first to be brought into the ponds and lakes, if the views advanced in this paper be correct. Afterwards the materials brought thither must be coarser. I will not, however, enlarge on a subject which I feel unprepared to discuss.

Prof. Emmons has described a rather unique case, occurring in New York, on the shores of lake Champlain. He finds there a deposit of clay, resting upon smoothed and striated rocks, yet beneath the principal deposit of drift; and moreover containing a few fossils of an arctic character. It would seem as if these shells continued to exist for some time after the commencement of the drift period, when nearly all organic life appears to have ceased; and that a reduction of the energy of glacio-aqueous agency allowed the formation of this deposit in that locality: after which its force again increased and covered the surface with detritus.

8. Contortions of the stratified Deposits connected with Drift.

Mr. Lyell has pointed out several remarkable examples in the drift of Norfolk, in England, of flexures and contortions, in which layers of clay are folded over upon one another for a short distance vertically, while the layers above and below are undisturbed. We have similar examples in the layers of the horizontal clay lying above the drift in our country. Nearly ten years ago I gave in my Report on the Geology of Massachusetts, the section (Pl. VIII, fig. 13,) taken from a clay pit in Deerfield. The vertical thickness of the contorted portion is about three feet; while above and below, the layers were undisturbed and horizontal.

Since the period above referred to, I have frequently met with similar cases in our clay. And at first view they seem very difficult to explain. But admitting the lakes, where the clay was in a course of deposition, to have existed at the close of a glacial period, we should expect that large masses of ice would have occasionally been carried into those lakes, and very likely partially stranded upon the bottom. Suppose them urged forward by the force of winds or currents, while thus partially resting upon the bottom. The consequence must have been, that the laminæ of clay, to the depth penetrated by the ice, would have suffered a lateral pressure, sufficient no doubt to fold them up and bend them over in the manner shown on the figure; while the laminæ beneath would have remained unchanged; and when the ice melted away, other laminæ would have been deposited upon the disturbed ones in a quiet manner and horizontal position.

9. Terraced Valleys.

I am not aware that the phenomena of terraced valleys are different in this country from what they are in other parts of the world; and, therefore, I need not go into a detailed description of them. Where they exist in the greatest perfection, we find two terraces on each side of the river, besides the present banks;

but more commonly there is only one terrace besides the bank. So far as I have observed, they almost always occur where there is a considerable expansion of the banks of the stream, and more or less of a gorge exists at the lower extremity of the basin through which the stream issues. I find Connecticut river to be thus terraced through almost its whole course, in numerous separate basins. Pl. VIII, fig. 14 shows these terraces, as they appear in Wethersfield, Vermont, seen from the opposite side of the river in Claremont.

Whatever may be the fact in regard to similar terraces at the mouths of rivers, where they are exposed to the action of the sea, it is clear that those in the interior must have been mainly produced by the waters of the river itself. For even if we admit the land to have been once low enough to bring every successive basin along a river upon the coast, yet the barrier at the lower part of the basin must have prevented an influx of the waves sufficient to wear away the softer deposits that bordered on the river. And I conceive that the waters of the river are sufficient to produce the existing terraces, if we only suppose, what no one will deny, that they gradually wear down their barriers. Nor do I conceive that the river must lower its bed by sudden and successive vertical movements of the land, or the water, in order to produce terraces. As to the manner in which the river might produce them by its ordinary movements, I must refer to my Final Report on the Geology of Massachusetts, since the description would be too long to introduce in this place.

But whatever theory we adopt as to the mode in which these terraces have been formed, nearly all will admit that the work began when the waters that deposited the clay and sand above the drift, had so far retired, whether by the upheaving of the surface, or the subsidence of the waters, that the upper terrace of the rivers was left bare; and that the work has continued nearly to the present time. Dr. Buckland supposes them to be the result of lakes, formed by moraines; and that they were gradually formed as the barriers of those lakes were cut through. If this be a correct view, we cannot regard these terraces as belonging to the period of drift exclusively; but as reaching also into the alluvial period: indeed, who can doubt that the work is even now advancing? And yet it began during the glacio-aqueous period.

10. Fractured Rocks.

I have discovered three examples in which ledges of rocks have been fractured at their top in such a manner, that it may reasonably be imputed to the agency of ice. One of these cases I found upon the western rail-road, in the town of Middlefield. Pl. VIII, fig. 15, shows the appearance of an excavation for the road, while yet it was in progress; that is, it shows the sides and end of the cut. The left hand side of the figure shows the south side of the excavation, and the right hand the north side. The rock in place is hornblende slate, whose strata stand perpendicular and run nearly north and south. Above the rock is represented a deposit of drift, about twenty feet thick. In the wall, crossing the excavation, are seen several cracks, to the depth of eight or ten feet below the surface of the rock, which are filled with mud and clay. These result from some force which has fractured the ledge to that depth, and bent the strata so as to make them incline towards the south. Similar cracks show themselves in the side walls. In short, the strata are broken off and pushed somewhat out of place, by a mechanical force. Now I can only say, that it is easy to conceive how such an effect might be the result of a thick mass of ice resting on this ledge, and crowded, either by expansion, or some other *vis a tergo*, down the deep valley where this spot is situated. But whether it was actually produced in that manner, I have no other evidence to show. It must have required a prodigious force, pressing southerly, to produce the fractures; and such a force ice could exert; and I hardly know of any other agent that could do it.

My second example is at Bruce's quarry of argillaceous slate, in the east part of Guilford, in Vermont, near the stage road from Greenfield to Brattleborough. The quarry is situated on the western side of a hill, of perhaps two hundred feet in height, and the laminæ of slate here stand nearly perpendicular, leaning however a little to the east, and running nearly north and south. The excavation has been carried on so far, that the wall of slate, on its east side, is in some places as much as twenty feet high. Yet towards the north end, the slate has not been excavated so far towards the east; so that as one stands in the south part of the quarry and looks northerly, he sees a mass of the slate projecting beyond the wall on his right, as is shown in Pl. VIII, f. 16, which was sketched from the south end. The upper part of the portion which thus projects, to the depth of ten or twelve feet from the top, is fractured and bent westerly, at all angles, even from ninety degrees to horizontality. To give this position to the broken laminæ, the force must have acted in a westerly direction, and considerably downward, as the top of the hill has not been affected.

That this fracture does not extend through the whole hill, is evident by examining its top and eastern part. Its western slope, above the quarry, is, indeed, for several rods, covered by trees, and a few feet of soil. But if we pass over the top a little, the slate comes into view, having the same strike and dip as at the quarry; so that a section crossing the hill at right angles to the strike of the laminæ, will present an appearance as in Pl. VIII, f. 17. At B, and C, the rock is concealed by soil, but visible at A, as well as along the fracture.

When I gave an account of this singular case in my first report on the Geology of Massachusetts, I was not able to suggest any theory as to the manner in which it could have been produced; so evident was it that the force must have acted at the surface and not from beneath. Subsequent reflection and more acquaintance with the enormous power of ice on the surface, and especially the discovery of the case just detailed in Middlefield, have satisfied me that the expansion of a vast mass of ice, resting on this spot, or its movement by any other agency, might have produced the fracture. The direction in which the force must have acted here, however, is nearly at right angles to that taken by the drift in that part of the country; so that if ice were the agent, it must there have made a lateral movement; perhaps in consequence of an enormous mass striking against the hill east of the quarry.

I must not omit to mention, however, that Dr. Jackson, in his report on the Geology of New Hampshire, gives an entirely different explanation of this case; referring the fracture of the laminæ to "a crossing and overlapping of the strata, forced out from their original position by a lateral thrust, which may have been effected by the elevation of the neighboring and subjacent primary unstratified rocks." — (*Geology of N. Hamp. p.* 57.)

Soon after noticing this opinion, I revisited the locality, and made a careful examination of it with reference to those views; and I must say that I could not discover the least evidence of any disturbance of the strata beneath the fractured laminæ; nor of any crossing and overlapping of the strata; nor of a lateral thrust; nor of unstratified rocks within several miles of the spot. If the figure accompanying Dr. Jackson's account was intended to represent the quarry, (of which I am not quite certain, from his language,) I must observe, that I could not discover, at the quarry, the thick mass of slate represented in his figure as lying in a northeast and southwest direction, and pressing against the fractured laminæ. The face of the quarry appears at first as if only the middle part of it had been subject to the crushing agency: but occasional fragments of the slate seen along the top of the quarry, beneath the soil, render it probable that originally the whole top, certainly all the northern part of the hill, was fractured in a similar manner to the part now exposed near the middle, and that the fragments have been swept away from the other parts.

I have thus frankly expressed my views of this case, not from a desire to enter into any controversy on the subject, but in the hope, that since Dr. Jackson and myself honestly differ about it, other geologists may be induced to visit the spot, in order to decide which of us, or whether either of us, has given a right explication of it. Such differences of opinion must be expected in geological investigations: but they will do no harm, if the opposite opinions be maintained with a proper spirit; with a readiness to abandon them when proved to be false.

Dr. S. L. Dana has pointed out to me a similar case of a fractured ledge of gneissoid rock, near one of the factories in the city of Lowell. It rises but a little above the surface of the ground, but its top is smoothed and striated throughout; and on its southeast side, the strata were found so much fractured, that it required only a crowbar to remove them to the depth of ten or twelve feet; and they have been taken away.*

11. Organic Remains in Drift.

This concluding head of the first part of this subject, will require but a few words. For it is one of the striking peculiarities of our drift, that it is almost destitute of animal or vegetable remains. Mr. Cooper has, indeed, made it probable, nay almost certain, that the remains of the large mammifers at the Big Bone Lick in Kentucky, are in drift. Indeed, it is highly probable that a large part of such remains, which have been found in the country, belong to the drift; so that we may regard it as containing the elephant, mastodon, megatherium, megalonyx, and Cervus Americanus. In the deposits of clay, above the common drift, in Canada, and beneath the drift in the north part of New York, a few shells of a highly arctic character have been found. It is stated, also, in the reports of the New York Geological Survey, that a plant has been found in a similar clay at Albany. It is certainly a remarkable fact, that although the beds of clay and sand connected with drift are more frequently excavated than any other rock formation in our country, there should have been discovered in them only the few organic relics above named. We

* It is gratifying to find that cases similar to those described in the text, are beginning to attract the attention of European geologists. The following description by Mr. Darwin, in his paper in the New Ed. Phil. Journal for Oct. 1842, *on the Ancient Glaciers of Caernarvonshire*, of a ledge of fractured slate in that country, corresponds very closely to the case in Guilford. " A little way down the hill," says he, " a bed two or three feet in thickness, of broken fragments of slate mixed with a few imperfectly rounded pebbles and bowlders, of many kinds of rock, is seen in several places to rest on the slate, the upper surface of which, to the depth of several feet, has been disintegrated, shattered, and contorted in a very curious manner. The laminated fragments, however, sometimes partially retain their original position" — p. 358. " May we not conjecture that the icebergs, grating over the surface, and being lifted up and down by the tides, shattered and pounded the soft slate rocks, in the same manner as they appear to have contorted the sedimentary beds of the east coast of England (as shown by Mr. Lyell) and of Terra del Fuego ? " — p. 359.

are justified in saying, as a general fact, that during their deposition, organic beings could hardly have existed in the vicinity. And yet some hundreds of years, it would seem, must have been occupied in their deposition.

Before proceeding to the theoretical part of this subject, it would be desirable to answer the inquiry, how far south in our country the phenomena that have been described are to be found? And from all the information within my reach, I incline to the opinion that scarcely any trace of drift, or striæ, exists in our Southern States. As yet we have no facts of any consequence stated by geologists, south of Virginia, on this subject. I know not what facts may be in the note-books of our southern geologists; but should not think it strange, if beyond the State just mentioned, no vestiges of glacio-aqueous action should be found, except perhaps upon the high mountains. And yet De la Beche states from personal observation, that Jamaica, in the West Indies, does contain erratic blocks, scattered by this agency: and the late Professor Hovey, who spent two winters in those islands, confirms this statement. We should not then be yet too sure how far south these phenomena extend. Professor H. D. Rogers informs me that primary pebbles do occur in Tennessee.

Theories of Drift.

Having occupied so long a time in describing the phenomena of drift, I must be brief in discussing the theories of its origin. And yet those theories have of late assumed a very interesting aspect.

If I am not much mistaken, geologists of every school, with perhaps a few exceptions, would now assent to the general proposition, that the phenomena of drift have been the result of the joint action of ice and water. They would differ as to the share which each of these agents has had in the work, while they would agree that both must have been more or less concerned. As I understand the subject, the principal diversity of opinion that now exists, relates to the mode in which these agents have acted in this mighty work, and as to their origin. The views that now prevail may all be reduced to three phases, or theories. I shall briefly inquire which of these accords best with the phenomena on this continent.

The first theory, so ably defended by Mr. Lyell, and I believe originating with him, supposes this work to have been accomplished mainly by icebergs, while the continent was beneath the ocean. It admits of a greater degree of cold than now prevails in the same latitude, and supposes that as the mountains emerged, even though not much above the waters, they would produce glaciers; which, descending to the shores of the ocean, would be floated away as icebergs, loaded with detritus, to a more southern region, and there deposit their load to form moraines.

That the greater part of the phenomena of drift on this continent must have been produced by icebergs, driven by currents over its surface, I can hardly doubt. And indeed, all the prominent features of this theory appear at first view extremely plausible, and many of them must be introduced into any theory of this subject that will apply at all to this continent. But to some features of it there are objections so serious as to be overcome with great difficulty. These relate principally, but not exclusively, to the vertical movements which our continent must have experienced, if the theory be true.

In the first place, I do not see that this theory, which is founded on the uniformitarian doctrine of existing geological causes, provides for the depressed temperature which must have existed to bring such vast quantities of ice over our country, as would be necessary to produce the striæ and accumulate the detritus. For if our continent was then mainly below the ocean, greater heat, instead of more cold, should have been the result.

In the second place, we have no evidence that glaciers have descended from any of our mountains; but we have proof, that the force which produced striæ and embossed rocks, acted upon the highest summits in the northern part of the continent.

In the third place, the vast deposits of vegetable matter, derived from land plants, in various places from Nova Scotia to the

Rocky Mountains, show that all the northern parts of our continent must have been above the waters long before the period of drift: for our tertiary strata are covered with drift, so that the agency which produced it must have continued to act, at whatever time it began, up to the commencement of the historic or alluvial period. Hence, after the deposition of the coal strata and the new red sandstone, the continent must have experienced such a depression as to bring the ocean over the whole of it, in order to produce the striæ and accumulations of drift. Afterwards, it must have been raised to its present height above the waters. Now who is prepared to believe that this continent has experienced such vast vertical movements so recently? Especially who can believe that the vast chain of the Alleghany mountains, more than six thousand feet high in New Hampshire, has all been beneath the ocean since the deposition of the tertiary rocks? And since we find the drift from all other formations spread over the tertiary, I do not see but every place from whence it was derived, must have been beneath the waters when it was accumulated.

It may be said, however, that our older mountains may have been above the waters long before the tertiary rocks; and that the marks of glacio-aqueous action on those mountains may have been produced an immense period of time earlier than that in which similar effects took place upon the newer formations. But to this idea I oppose, first, the fact that the phenomena of drift have an almost equal freshness and apparent recentness on the oldest and the newest rocks: secondly, the fact that bowlders have been carried, in many instances, from lower to much higher levels: thirdly, the fact that the northern slopes of our mountains are often striated, several hundred feet below their summits, by a force directed upward. Finally, if our higher mountains were above the waters before glacio-aqueous agency took place at lower levels; if, for instance, the ridges of the Alleghany chain, from Alabama to Canada, were dry land when this agency was in operation upon the lower rocks along the Atlantic coast, then, I ask, how the drift could have been carried southeasterly from the ridges already above the waters; and how the striæ should so generally have a northerly and southerly, or northwesterly and southeasterly direction, showing that the icebergs and currents came from that direction? I am unable, I confess, to conceive how our phenomena of drift can be explained, without supposing nearly the entire surface beneath the waters when they were produced; and that the work was accomplished nearly at the same time, — that is, within a few centuries, or thousands of years, — at all altitudes.

If it be said that particular mountains may have been raised, like the Alps, from the ocean, since the period when glacio-aqueous agency commenced, while, as a whole, the continent has been raised but slightly, I reply that such an event could not have taken place without producing local disturbances in the moraines, and among the striated and embossed rocks, around such mountains; as has been the case in the drift of the Alps: and that as yet no example of such disturbance has been pointed out. Every careful observer of these phenomena, it appears to me, will come to the conclusion, whatever be his theoretical views, that if this continent has been recently elevated, it must have been as a whole; and that the relative levels of the surface have not been altered, since the glacio-aqueous period, to any great extent.

These are certainly very strong objections to this iceberg theory of drift. I admire the theory, however, and should prefer it to all others, if these objections can be removed. Another theory advocated by M. De la Beche, supposes the contents of the northern ocean, aqueous and glacial, to have been precipitated over the countries further south, by the elevation of the regions around the pole. This theory avoids the difficulties connected with the vertical movements of our continent, by furnishing an ocean to cover it at its present level. It furnishes also the requisite icebergs, without a previous change of climate, and a cause for the glacial period, which prevailed during the accumulation of drift. Applied to the low countries of northern Europe and Asia, it may be adequate to the effects. But on this continent we want an ocean to rise six thousand feet above the present sea level, and the southerly currents in it to continue at least for centuries, to produce all the erosions clearly referable to glacio-aqueous action. Can either of these effects have been the result of the elevation of the bed of the northern ocean by volcanic agency? Have we any example on record that will justify us in assigning such effects as we witness to so apparently inadequate a cause?

The glacier theory of Agassiz supposes an immense accumulation of ice and snow around the poles during the glacial period, which sent out enormous glaciers, southerly of course, by which a part of the phenomena of drift was produced, and as the ice melted away, upon the return of a warmer period, the oceans of water thence resulting, produced southerly currents, which transported icebergs and detritus in the same direction, and thus finished the work begun by the glaciers. This theory, equally with the last, furnishes an ocean, icebergs, and cold. It happily explains, also, and so does the last theory, two facts with difficulty reconciled to the first theory, namely, the transportation of detritus from lower to higher levels, and the smoothing and furrowing of the northern slopes of mountains. That these would be natural effects of icebergs, urged southerly in an ocean which was gradually rising over the land, so as to lift those icebergs to higher and higher levels, is obvious: but how they could be produced when the land was rising out of the ocean, and the water consequently retreating, I am unable to conceive.

If the glacial theory undertook to explain all the phenomena of drift by the action of common glaciers, it would not need a moment's argument to show its entire inadequacy to account for those phenomena in this country. But when it admits, as a legitimate part of it, that accumulations of ice to an unlimited extent may have existed around the poles, and that the return of heat, by melting that ice, must produce southerly currents, and even vast deluges, for a long period, a new aspect is put upon it, and we listen with attention to its advocates. I confess, however, that as usually advanced by its able originators, it does not seem to me to furnish a cause adequate to the effects. To account for all the phenomena in this country, we want currents of water to flow over a large part of the surface, loaded with ice and detritus, for centuries at least. Now it is usual to speak of the accumulation of ice around the poles during the glacial period, only to the thickness of a few thousand feet. This is certainly far too small an amount to satisfy the above conditions. If we might suppose, that as a consequence of the earth's ceasing to turn on its axis, the water should accumulate, as it naturally would, around the poles to the depth of thirteen miles, and become converted into ice, and then upon the renewal of the earth's diurnal motion and the return of heat, be slowly melted away, we should have a source whence water and ice could be made to flow southerly for a long period. This supposition is, to be sure, a highly hypothetical one; and yet not impossible: nor can I conceive that the glacier theory furnishes an adequate cause for glacio-aqueous agency on this continent, till it shall point out an equally prolific source of long continued cold, icebergs, and southerly currents.*

Mr. Maclaren has recently suggested an ingenious amalgamation of the iceberg theory of Lyell, with the glacier theory of Agassiz. He has rendered it very probable, that if most of the present continents of the globe were beneath the ocean, there would exist a broad westerly current between the tropics, and two easterly currents between the tropics and the poles. Such he supposes to have been the state of the northern hemisphere during the glacial period. He also supposes, with Agassiz, that during the same time, there was a vast accumulation of ice around the north pole; which, upon the return of heat, would send off cur-

* I regret to find that the President of the London Geological Society, (*see Mr. Murchison's Address before that Society in February*, 1842,) has understood me in my Address before the Association of American Geologists, to be committed to the unmodified glacier theory of Agassiz. Much more do I regret, that he seems to identify the views of American geologists with mine. I did, indeed, express myself strongly in my admiration of the ingenuity and ability with which the subject was treated by that distinguished naturalist, and in my joy at the new light which the history of glaciers seemed to me to shed upon the phenomena of striated, smoothed, and embossed rocks, and the formation of moraines; but I certainly never imagined that his theory, *unmodified*, would explain the phenomena of drift in our country. And this I stated three times in that Address. I also stated what was the grand conclusion to which my mind had come in view of all the facts; namely, that "glacio-aqueous action (by which I mean the joint action of ice and water, without deciding which has exerted the greatest influence,) has been the controlling power in producing the phenomena of drift." My general views on this subject were the same when I wrote my Address, as when I wrote this paper; except that in the latter, they are more matured and carried out into details.

rents southerly; and these, meeting with the easterly currents, the result would be a current compounded of the two forces; that is, a southeasterly one, — the very direction that seems to have been generally taken by drift over the whole northern hemisphere.

We might perhaps proceed a step further, and say, that in the effects of present or past agencies, we can recognize the conditions essential to all the preceding theories. In the floating icebergs of the northern and southern hemispheres, we have an example of the transportation of bowlders and smaller detritus from high latitudes towards the equator. In the glaciers of the Alps and other mountains, we can see the precise manner in which the striation, smoothing, and rounding of the rocks, and the accumulation of gravel and sand in ridges and tumuli, may have taken place. And in the recent elevation of the Alps and the dispersion of drift from the axis of the mountain, as well as from some of the mountains of Great Britain, and perhaps of Northern Continental Europe, we see the effects of the elevation of large masses of land from the ocean. Is it not therefore possible, that the phenomena of drift may have resulted from all the causes advanced in the theories under consideration; and that the ultimate and true theory on the subject may be compounded of them all?

But whichever of the preceding views shall prove true, I feel as if we might now safely take our stand on this conclusion, that the proximate cause of the phenomena of drift has at last been determined, namely, the joint action of water and ice. The dynamics of this most difficult subject seem at length to be settled. And now suppose we cannot go back, and determine certainly the origin and mode of operation of these agencies. This will not make it any the less certain that they have existed and have operated. And perhaps geologists will be obliged to content themselves with this conclusion, however gratifying it might be to curiosity, to trace from the beginning, the *modus operandi*. What if they should never be able to satisfy themselves which of the varieties of theory above described is the true one? Yet have they reached an immense conclusion, when they have shown, as they seem now to have shown, that the surface on which we dwell, that a large part of the northern hemisphere, and probably of the southern also, has, at no distant period, been swept over by water, bearing along the field ice of an arctic or antarctic ocean; that the ridges and hills of gravel, which we meet every where, have been dropped or crowded along into their present shapes and places by these floating masses of ice; that these have grated along the surface of our mountains and valleys, and swept down their salient parts, and left the surfaces smoothed, rounded, and striated. Truly, in such conclusions as these, there is not only novelty, but sublimity.

In other parts of geology, and of other sciences, we are obliged to stop when we have reached the true dynamics of the subject. And the fact that so many geologists have ventured beyond this into the field of hypothesis, has thrown an air of uncertainty over the whole subject, in the view of those who do not distinguish legitimate conclusion from dreamy hypothesis. No science has suffered so much from this cause as geology; just because it opens vistas into the arcana of time, too long for human ken to reach their extremity. But it does not make the existence and form of the links of a chain near to us any more uncertain, because that chain reaches so far that some of its links are invisible.

One of the most interesting aspects in which the facts and theories concerning drift now present themselves, is the evidence they afford of a rapid approach to unity of opinion among geologists, and of a consolidation of geological principles. This has certainly long been one of the most chaotic parts of the science. But difficulties have given way before accurate examination, and the accumulation of facts; and already, unless I am mistaken, the proximate origin of drift is determined; and by carefully considering those theories on which there is yet a diversity of opinion, we shall see that they differ but slightly; and that those differences respect points, which may always remain doubtful; and which, therefore, geologists may discuss without feeling that any thing important depends upon the decision, and with the most enlarged charity towards those who differ from them. How very different then is the state of this subject to-day, from what it was, when some of us first began to look at bowlders and striæ, more than twenty years ago!

And if such is the approximation of opinion to unity, in this more unsettled part of geology, equally cheering is it to look at other departments of the science. Not many years since, the main controversies related to the nature of the causes of geological change. Now, by means of the labors and reasonings of able men, and eminently of the distinguished gentleman* from the land of our fathers, who has honored our country with a geological visit, and this meeting by his presence, the ground of dispute is narrowed down to a consideration of the intensity of causes in whose nature all agree. It is possible that the question of uniformity and of catastrophes may never be completely settled: and quite possible also, that a complete physical theory of geology may never be attained, because beyond human sagacity. Yet phenomenal and inductive geology is fast assuming a fixed and symmetrical form in all its parts: and when this work is completed, inquiries into the origin of things, may lawfully form the pastime of geologists.

On a New Species of Trilobite of very large Size. By John Locke, M. D., *Prof. of Chemistry and Pharmacy in the Medical College of Ohio. Read April* 6, 1841.

Isotelus Megistos.

Clypeo *antice elliptico, attenuatè marginato, posticè arcuato, et terminato utrinque aculeo; caudâ posticè ellipticâ, anticè arcuatâ; articulis abdominis octo.*

The shield is anteriorly nearly perfectly elliptical, broadly and thinly margined, posteriorly arcuate, and terminated at the angles by spines or pointed processes extending backwards beyond the two first abdominal articulations. The eyes are prominent, large, furnished exteriorly each with a crescent-shaped cornea, and

* Charles Lyell, Esq.

placed rather nearer to the posterior edge than to the outer margin of the shield. From the corner of each eye a sutural line extends forward, meeting at the anterior margin of the shield, and enclosing a lozenge-shaped, leaf-like frontal space. Abdomen trilobed; middle lobe cylindrical; articulations eight, bending flatly over the middle lobe, and descending abruptly at their lateral extremities, which are broad, flat, and rounded beneath, and admirably fitted to sliding over each other when the animal should contract or roll himself, according to a well-known habit of the genus. Tail posteriorly elliptical, anteriorly circularly arcuate, length measured horizontally, less than two thirds of the width, having two obscure longitudinal depressions continuous with the abdominal furrows, and converging towards an obscure posterior tubercle. The anterior outline of the tail exhibits three slight lobes, (corresponding with those of the abdomen,) the two exterior of which are very distinctly marked by a transverse depression.

When the posterior shell of the tail is decorticated, an interior shell is exposed, which forms, all around, a deep trough or "cavetto," beautifully marked with a "venalian" of eccentric curved and branched lines. The above named posterior tubercle is very nearly the "focus" of the "elliptic" outline of the tail, is just anterior to the marginal cavetto, and is the centre around which the curved lines originate, each passing a little further back than the other, and advancing outwardly and forward until they successively disappear on the anterior margin of the "cavetto."

Distinctions. — This *Isotelus* resembles the *gigas*, from which however, besides the aculeate processes, it is distinguished by the perfectly elliptic terminations, by the simple (not raised) margin of the shield, and by the proportions of the tail, the *gigas* having the length four fifths, and the *megistos* three fourths only of the width. The latter is also much more prominent than the former, and the tail and sides much more abrupt in their descent. From the *megalops* and the *stegops* it is clearly distinguished by the eyes.

History and mathematical proportions. — The first fragment (see outline on Plate VI,) was discovered by myself in Adams county, Ohio, in 1838. It was about six inches of the marginal "cavetto" of the tail, beautifully veined, marked with the tubercle, perfectly elliptical, and coinciding with the end of an ellipse twenty-two inches long and twelve inches broad. The second specimen was an entire tail found at the same locality; this, upon admeasurement, was found to coincide with an ellipse of exactly half of the dimensions of that which suited the first specimen, and showed, by a fortunate fracture, the internal marginal cavetto. These two specimens were both figured and described by me in the Ohio Geological Report for 1839.

The third specimen (see outline) was discovered in the autumn of the same year by Wm. Burnett, Esq., on the hills at Cincinnati, and presented to me soon after. It was partly covered by the crystalline blue limestone in which it had been imbedded, and it was not until the winter of 1840–41 that I dissected it out of its gangue, and found that it had an aculeate shield, and that it exhibited the animal almost entire.

It is of the same dimensions as the second specimen, and measures nine inches and three fourths in length, and six inches in breadth. The first fragment must therefore have been from a specimen nineteen inches and a half long, and twelve inches broad. These gigantic dimensions suggested the name *maximus*, which I gave in the Ohio Report, but which, for obvious reasons, I have changed to the more classical Greek term of the same import.

The fourth specimen was discovered by Mr. Carley, of Cincinnati, who was the first to discover the aculeate shield, for in the Burnett specimen this character was still concealed. Mr. Carley's specimen appears to be a young one, for it is only about three inches long. It was obtained in the bed of the Ohio river about four or five hundred feet lower than the situation which furnished the Burnett specimen. My own first specimens were found within thirty feet of the top of the blue limestone formation, where it is overlaid by the cliff limestone. Now the character of this magnificent species of trilobite has been ascertained, it is evident that fragments of it are abundant in our blue limestone, which is undoubtedly the equivalent of the limestone of

Trenton Falls, N. Y., called the Trenton limestone. The most common fragment found is the corner of the shield with its thorn-like appendage, (see the figure, Plate VI.) For the information of geologists, I would observe, that fig. 2 was found just below the stratum most abundant in the genera *Delthyris*, *Turritella*, and *Trochus*, and that Mr. Carley's specimen occurred in the region of the *Isotelus gigas*, and the *Cryptolithus tesselatus*.

On the Origin of Mineral Springs. By Lardner Vanuxem, of Bristol, Pa.

At the last meeting of the Association, a paper "On the Sulphur Springs of New York" was read, by Dr. Lewis C. Beck; and having dissented from the opinion advanced by the writer as to their origin or source, I proposed to present my views at the next meeting of the Association.

There was no discordance of opinion as to the facts set forth in the paper, but dissent merely, from the conclusion drawn from the facts, attributing to the springs a volcanic source or origin.

At that meeting it was not the intention of the dissenter to confine himself to sulphur springs, because the proof of a more local origin than a central source might not be so conclusive to others, if treated singly, but to include those of other kinds that were in the same category, so that their united weights would insure a decided preponderancy.

Furthermore, aware of the importance of Mineral Springs to explain the origin of the contents of all veins, &c., that were fissures, cracks, &c., it was the intention also of the dissenter to direct attention to them, as the vehicle of the product of veins, and if not successful at the time, it might open the way, probably, for a future effort which would be final, either positively or negatively.

Two opinions now divide geologists as to the origin of such veins. One regards them as the result of injection from subterranean sources, similar to the origin which Dr. Beck ascribes to the Sulphur Springs of New York; the other ascribes to segregation, the materials having been furnished by the rock either by transudation or percolation of moisture or water, aided by that power which exists, wherever dissimilar masses and dissimilar particles co-exist.

It must be obvious, that should the connection between the source of mineral springs, and the rock from which, generally, they issue, be established, it would give a decided bias to the doctrine of segregation, if it did not fully establish it.

There is no intention in this communication, to absolutely confine the source from whence waters have derived their mineral contents, to the rock from whence they issue, excepting generally; for the fact is well established, that most, if not all of our thermal springs, as well as those of other countries, are connected with faults, and have come from great depths, as their temperature makes manifest; but to those only where no faults exist, the temperature of which is usually that of common springs, being about the mean annual temperature of their locality, such as the sulphur springs of New York, its brine springs, its acidulous saline chalybeates, &c.

It is proposed to show that the rock from whence a mineral spring or springs issue, as a general rule, has given origin to them; there being a general connection as to kinds of springs and rock: that though the same kind of water may issue from different kinds of rock, as in the sulphur springs of New York, yet the number of the springs and the quantity of water of the kind which discharges along the long line of undisturbed gypseous rock of that State, show a connection with the rock, which would not be the case were the sulphur water of volcanic origin; for it then would appear by fissures from those below that rock, which is not the fact in any instance, either as to number of springs, or quantity of water, they being but few, and yielding but little water comparatively, though the position of that rock, at the north end of Otsego county, and in Herkimer and Oneida counties, are highly favorable for springs appearing at a lower level.

The whole of the thermal springs of the United States, those of Hoosic, Lebanon, Virginia, Buncombe county, North Carolina, and Washita, in all probability have one character as to origin, that of issuing or rising through faults, and having been raised from a great depth, as their temperature indicates. They are of importance as to the point in question, from their negative character, being neither saline nor sulphureous, or what is termed mineral, excepting those of Washita, which have left, or leave a deposit of calcareous tuffa, iron and gypsum. These springs, were it true that the sulphur springs of New York owe their mineral nature to a subterranean or volcanic origin, would, from the great depth from whence they spring, be the most likely to contain sulphur; but they contain none, and the whole of the New York springs of that kind, are placed above those of the thermal ones, as to their surface rock, if we except those of Washita. Of their rock, we cannot say that we know it, from the reports published of that region. The thermal springs are those which have come from the greatest depth, and are connected with the oldest rocks, appearing to have originated between the primary and the transition classes.

The next kind, as to rock or age, are the acidulous saline chalybeates, those only of New York being considered. They form the well-known waters of Saratoga and Ballston, to which those of the borings at Albany, and Halleck's spring in Oneida county, are added, being of the same, but of an inferior nature. The whole belong to the Hudson river group, issuing from, or obtained by boring in that group.

Ascending higher in the series in New York, are the brine springs of the Medina sandstone, characterized by the *Fucoides Harlani.* These springs are numerous, commencing in the county of Oswego, and appear in Cayuga, Wayne, and others further west. They are the lowest springs in the State, with the exception of one, which contains salt in such purity and amount, as to be entitled to the appellation of brine springs. For some time, their rock or source, and the one from which the salines of the State derive their salt, were considered to be one and the same. Two groups of rocks separate the two, the Niagara and the Clinton groups, above which, and above the red shale, the base of the Onondaga salt group, is the position of the greatest number, and most copious springs of sulphur waters.

The fact is certain, that north of the Highlands, and west of the Hudson, sulphur springs are extremely numerous, and are seen issuing from most of the rocks, from the Utica slate, to the Catskill group; but it is equally true that sulphur springs are far more numerous and more copious in the Onondaga salt group, which group, as before stated, may, in New York, be considered comparatively as the peculiar position of such springs.

In all that part of the State where its Sulphur Springs are most numerous, there are none which will, for abundance of waters, compare with those which issue from the group in question, and usually below that part which corresponds with the range of plaster masses; such as Charm springs, springs north of Cherry Valley, Sanquoit springs, those of Chittenango, Lake Sodom, Messina springs, &c. &c. So abundant are the waters from that part, along the whole line of the group, and so few and small are those below and above that line, that the admitted fact in mining, that all waters are from the surface, making their way through the rock, either by its mass or fissures or both, appears to be confirmed by these springs, so local do their nature or origin appear.

In the dissent, there was no intention to prove that the mineral contents of the waters actually existed in the rocks; but to show from the connection of rocks and springs, and from the existence of a series of different kinds of mineral springs, one placed above the other in geological position, that their origin must be local, and not foreign or volcanic, and, as a necessary consequence, the materials must exist in the rocks of their source.

To prove the existence of materials so small in amount as those required for mineral springs, could not be expected by ordinary analysis, which rarely reaches beyond the tenth part of a grain. Where it ends, the mind, to a certain extent, must take its place. All are aware that waters may permeate masses of rock of miles in extent, and that large bodies, by a *leaching* of the kind, may yield materials which, in the quantity used for analysis, would be wholly imperceptible. Native sulphur, however, has been found in two localities with gypsum, one in Onondaga, the other in Cayuga county.

In the same group with the Sulphur Springs, but above them, generally, and between the beds of gypsum, are the Hopper or salt cavities, and the porous or vermicular rocks of Prof. Eaton; the pores of which were evidently due to a soluble salt, in which occasionally, Hopper cavities are observed. This part of the group is, without question, the outcrop of the source of the salines of Onondaga, and of Cayuga at Montezuma. The existence of the Hopper cavities is highly satisfactory, showing the source from whence the brine waters obtained their salt, and that the origin of those waters was local. But for this fact, though the connection between the salines and the group which contains the gypsum be perfectly established, yet the same obscurity would exist as to their source, as exists with the Sulphur Springs of New York, to which a remote and volcanic origin was given.

From the fact that thermal waters hold the lowest position, we assert their connection with faults, by which they rise from the source of their origin, placed between the Primary and Transition classes, the classes unconformable to each other, where such springs exist, being undeniably the most favorable position in our country for the manifestation of volcanic agency; yet, as their waters, are neither sulphureous, saline, or acidulous, they negatively, as to their nature, oppose the view dissented from, and positively, by showing that no connection or communication can exist between the source of volcanic action, which must be below that point, and the class to which the Sulphur Springs of New York belong, as the thermal springs hold the intermediate position.

Secondly, that acidulous saline waters, as a class, occur next in position above the thermal ones in the Hudson river group, and when the rock is both disturbed, and undisturbed, showing a local origin as to rock. These are followed at a higher level by the brine springs of the Niagara or Medina sandstone, above which, and separated by two other groups of rocks, are the principal sulphur springs of that State, the whole series of rocks where the sulphur springs are so copious being undisturbed. Next to them, are the Salines of the State, and in the proof shown of their local origin, we find analogically also the proof of the local origin of all the others.

The facts from New York make known, as it appears to me, this important result, that a connection exists between certain rocks or parts when complex, and certain kinds of waters; and that rocks, generally, insulate their own waters.

It may be necessary to state, that the nature of the materials, whether volcanic or otherwise, either wholly or partially, from whence the waters issue, is not the subject discussed, but the disconnection totally of those waters with any actual volcanic source, confining them generally to the rock from whence they appear.

In commencing this paper, it was the intention of the writer to condense the whole subject within a few pages, the application therefore, of mineral springs, by means of water or moisture holding mineral substances in solution, to the filling up of the cavities or fissures of rocks, will be reserved to the next meeting of the Association.

Ancient Earthworks of Ohio. By Prof. John Locke.

Earthworks of great antiquity and of various construction are found scattered over the whole Western Valley. It is true that in a few instances mistakes have been made in respect to them, a natural conical hill having been called a "Mound." No doubt such an error was committed by the geographer, the late Rev. Mr. Flint, with reference to some ranges of conical hills west of the Mississippi. This error having been corrected and reviewed by

Judge Hall, of Cincinnati, we were surprised to learn that Prof. Hitchcock, taking this instance in a sweeping and general sense, had announced in his geological report, that most of the supposed artificial earthworks of the West, had been discovered to be natural. This was at once seen to have been a mistake on the part of this eminent geologist, originating no doubt in expressions not sufficiently qualified and guarded on the part of Judge Hall. We had hoped before this, that his views had been corrected. As they have not, I here introduce a few remarks to prove their artificial origin.

The topography of the greater part of the Western Valley differs widely from that of New England. There we have every evidence that the original surface was a very even, almost level, table; and that the present form has been produced by the erosion of streams, the larger of which have cut their channels to the depth of about six hundred feet, and opened alluvial valleys from one to four miles in width. A map therefore of the water-courses is an outline of the whole of the simple topography, on which the traveller may rely with so much certainty, that he may by means of a map alone, plan his own road, and travel uninterruptedly, with horses and wagon, for weeks or months, over a pathless region, without inquiring his way or employing a guide. Even the parts of the country covered by diluvium are smoothly covered; there are no pot holes, no sand hills, no ridges of drift. It is true there are a few conical outliers on the crests bordering the river valleys, and sometimes in the alluvians, as in the American bottoms, as described by Judge Hall; but these are mostly distinguished, by the common inhabitants even, in consequence of stratification evident in the materials of which they are composed. The mountain outlines on the upper Mississippi have been called "Mounds" by a very natural figure of speech, not because they were supposed to be artificial, as Sheralds, Sinsinaway, Platt, and Blue Mounds, some of which are a thousand feet high, and are composed interiorly of massive stratified rocks to the above height, containing in some parts veins of lead ore in place. Now in the midst of the smooth boundless prairie, on the top of the level wood-covered terrace, or on the even, broad alluvium of the mighty rivers, precisely in the situations where we should least expect any surface disturbance, we are surprised by the huge basso-relievos of earthwork antiquities.

There seems to be rather a provoking disposition on the east of the Alleghanies to doubt the truth of our accounts of these antiquities. After I published the account of my survey of an extensive earthwork on Fort Hill, in Highland county, Ohio, it was very generally copied into the eastern newspapers. This drew forth a malignant paper from an anonymous scribbler, who pretended to have seen the same works, charging me with absolute falsehood. This charge, unfounded and unauthenticated as it was, appeared immediately in the same eastern papers. But my refutation, in which I clearly showed, from his own account of the locality, that the author of the attack had never seen the works described by me, though probably he had witnessed some inferior ones *eight or ten miles distant*, was never noticed by those papers, and I stand to this day charged, on anonymous authority, with the crime of wilful falsehood.

The very great number of those works in the West seems not to be generally known. As near as I can recollect, in Butler county alone, there are about twenty of them, and I should estimate the average number to be not less than twelve to each county in the State; not mere mounds, but many of them extensive lines of ditch and embankment. The beautiful plain on which Cincinnati now stands, was, in the words of Gen. Harrison, "originally literally covered with them." That they occur in situations where above all others we should expect the surface to be even and undisturbed, that they almost always occur at points commanding the most extensive and beautiful prospects; that the materials of which they are composed are not stratified, but consist often of diversified parcels of clay, loam, mould and gravel, in masses about equal to hand-barrow loads, confusedly thrown together; that they are superimposed on the black mould of the original surface, on which are often ashes and charcoal of ancient fires; that they contain artificial utensils, carbonated maize grains with even the "cob," leaves and stalk of that plant, and human skeletons quite to their base; that they bear evident marks of design, and sometimes have imitative forms, as that of birds, lizards, bears and panthers,* carries perfect conviction to the minds of persons most familiar with them, that they are the result of human zeal and perseverance. The most common form is either an isolated circular tumulus, from the lowest perceptible, to those which are ninety feet in altitude, or long lines of embankment often enclosing an area of from one acre to several hundred acres. In some places these embankments approach nearly to some mathematical figure, as a square, a circle, or an ellipse; in others again, their form has been determined by the shape of the ground, especially where the work occupies the top of a terrace, when it follows the highest crest or verge of the declivity along the edge of the surrounding ravine. But my object is not so much to describe these works, as to make use of them as geological monuments by which to determine some facts with regard to recent surface action.

The degree of antiquity of these works, a problem of vast interest, has not yet been determined. We have however data for a negative solution to some extent, as we have in reference to the distance of the fixed stars, the want of parallax of which shows them to be beyond a very remote limit. It will be seen by reference to the second Ohio Report, p. 269, that on the embankment of a work in Highland county, Ohio, already referred to, there were a chestnut tree, six feet in diameter, and a tulip poplar, seven feet in diameter, the former having six hundred, and the latter, six hundred and seven annual grains of growth. As it would probably be several years after the commencement of these works before their completion, and several years more before any trees would be permitted to grow upon them, I estimated their origin to have been at least one thousand years anterior to the time of my examination. General Harrison, in his late address on the subject of the Aborigines, by the following reasoning, extends the period much further. He states, on the authority of his own observations in the West, that when the forest trees have been once cleared from the ground, and a new growth shall have

* See Mr. TAYLOR's account of the "Animal Effigies" of Wisconsin, published in Prof. Silliman's Journal. Having examined the same locality, and re-surveyed the same works, I am happy to add my testimony to the faithfulness of that gentleman's descriptions.

been suffered to spring up, it will not be the usual mixture of several species of trees, but will be exclusively of one species, as perhaps the locust, possessing and overshadowing the ground to the exclusion of all others.

From this he infers that after such works were executed, several generations of trees must have succeeded each other before the forest would have assumed the same mixed character on, and within the works, as that possessed by the surrounding forests; a character of which we never find them now to be destitute, the species being the same and of the same size to the very top of the works, as in the surrounding and contiguous localities. Indeed the trees on the embankment have sometimes outgrown their neighbors, evidently from having an accumulated depth of dug or tilled soil to support them. This view of the subject would carry back the origin of these antiquities to the Christian era, and possibly beyond it. Now the point which I propose to determine, is whether the waters of the great western rivers are now sensibly lower than at the origin of the earthworks. These antiquities evidently occupied all levels from high-water mark to the tops of the highest hills; and had there been, since their construction, any general subsidence of the waters, either by diminution of quantity or by deepening of channels, none of them would now be found to approach within the distance of such subsidence. But the fact is that numbers of those works do now extend to high-water mark, and some of them are occasionally very partially submerged. The general inference is then, that, for more than a thousand years, at least, there has been no subsidence of the streams. Whether the earthworks were ever carried much below high-water mark cannot perhaps be decided, for had that been the case, it is probable that repeated inundations would have obliterated them.

At Colerain, on the Great Miami, about twenty miles from its mouth, there is an earthwork embankment enclosing about one hundred acres. This work is mostly entire, but extending as it does on a low alluvion, in a few places it has been overflowed, at extraordinary floods, and here it becomes obscure or is entirely obliterated. From this I infer that the channel of the Miami below that point has been actually filled up. This would be likely to take place since the banks, from being stripped of trees, the roots of which protected them, have been extensively undermined and precipitated into the stream. The Colerain embankment was probably a work of defence, as it commanded a peninsula formed by a bend in the river of two miles in circumference. It has been thrown up from a ditch on the outside, which, passing through loam into the substratum of gravel, gives, in a transverse section, unequivocal evidence of its artificial origin. Pl. X, f. 2.

The most interesting work confirmatory of the view taken, namely, that the degradation of the surface has been very slow, is on the Little Miami, about thirty miles from Cincinnati and about six miles east of Lebanon, in Warren county, Ohio. This work occupies a terrace on the left bank of the river, and two hundred and thirty feet above its waters. The place is naturally a strong one, being a peninsula, defended by two deep ravines which, originating on the east side near to each other, diverging and sweeping around, enter the Miami, the one above and the other below. The Miami itself, with its precipitous bank of two hundred feet, defends the western side. The ravines are occcupied by small streams. Quite around this peninsula, on the very verge of the ravine, has been raised an embankment of unusual height and perfection. Meandering around the spurs and reëntering to pass the heads of the gullies, so winding is its course, that it required one hundred and ninety-six straight lines to complete its survey. The whole circuit of the work was between four and five miles. The number of cubic yards of excavation was approximately 628,800. The embankment stood in many places twenty feet in perpendicular height, and although composed of a tough diluvial clay, without stone except in a few places, its outward slope was so steep as from thirty-five to forty-three degrees. This work presents no continuous ditch, but the earth for its construction has been dug from convenient pits, which are still so deep as to be filled with mud and water. Although I had brought out a party of a dozen active young engineers from the Pleasant Hill academy, and we had encamped upon the ground to expedite our labors, we were still two days in completing the survey, which, with good instruments, we conducted with all possible accuracy.* The work approaches no where within many feet of the water of the river, but its embankment is in several places carried down into ravines from fifty to one hundred feet deep, and at an angle of thirty degrees crossing a streamlet at the bottom, which by showers must often swell to a powerful torrent. But in all instances the embankment may be traced to within three to eight feet of the stream. Here it appears, that although these little streams have cut their channels through fifty to one hundred feet of thin horizontal layers of blue limestone interstratified with indurated clay marl; not more than three feet of that excavation has been done since the construction of the earthworks. If the first portion of the denudation was not more rapid than the last, a period of at least thirty to fifty thousand years would be required for the present point of its progress. But the quantity of material removed from such a ravine is as the square of its depth, which would render the last part of the denudation much slower, in vertical descent, than the first part. That our streams have not yet reached a "constant regimen," a point beyond which they cease to act upon their beds, is evident from the vast quantity of solid material transported annually by our rivers, to be added to the great delta of the Mississippi. Finally, I was astonished to see a work simply of earth, after braving the storms of thousands of years, still so entire and well marked. Several circumstances have contributed to this. The clay of which it is built is not easily penetrated by water. The bank has been and is still mostly covered by a forest of beech trees, which have woven a strong web of their roots over their steep sides, and a fine bed of moss (Polytrichum) serves still further to afford protection. Many interesting points of antiquarian research suggest themselves in connection with this examination, but as they have no special geological bearing, I abstain from their discussion. I will only add, that the full interest of these antiquities will never be developed unless by minute and strictly accurate surveys, calling for more labor and expense than are likely, under ordinary circumstances, to be bestowed.

* The "engineers" referred to were, David M. Wilson, John S. Lane, John Silsby, Joseph G. Wilson, James Garrard, Israel L. Garrard, Alfred John, Wm. H. Scott, Andrew McMickin, Thomas F. Jones, and John Locke, Jr.

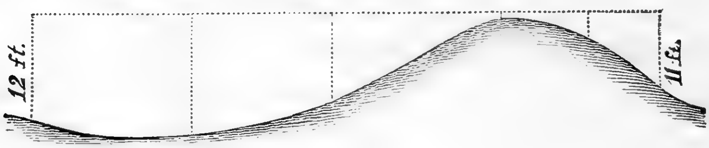
I give below some cross-sections of the great earthwork on Little Miami: (Pl. X.)

Cross-Sections of the Embankment.*

Field Notes of Cross-Section marked (a) on the Map.

No. of Station.	Distances.	Heights.
1	0 feet.	12 feet.
2	18	13
3	15	9.0
4	10	4.2
5	12	1.4
6	10	5.2
7	8	11.0

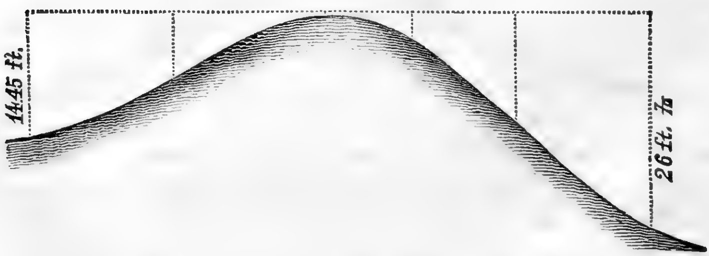
Plan of the above Section on a scale of twenty feet to the inch.



Field Notes of Cross-Section marked (b) on the Map.

No. of Station.	Distances in feet.	Heights in feet.
1	0	14.45
2	17	6.83
3	15	0.6
4	13	5.6
5	13	17.8
6	18	26.7

Plan of the above section, scale twenty feet to the inch.

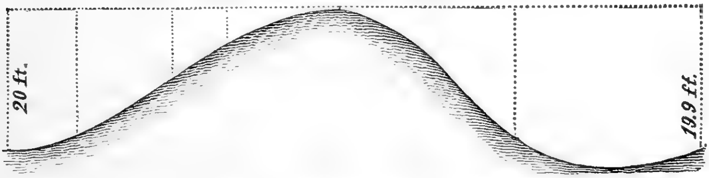


* These sections were surveyed from a single station of the levelling instrument, such as to range over the top of the embankment; from this plane perpendiculars were measured downward, at such distances as are indicated in the notes.

Field Notes of Section marked (c) on the Map.

No. of Station.	Distances in feet.	Heights in feet.
1	0.0	20.0
2	9.0	18.4
3	14.5	11.1
4	9.6	5.2
5	13.3	0.7
6	23.3	18.0
7	26.8	19.9

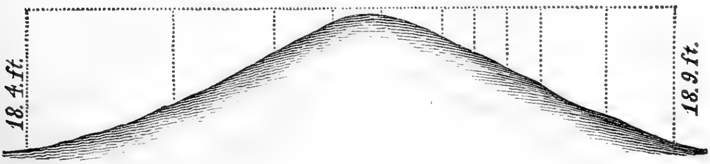
Plan of section (c) on a scale of twenty feet to the inch.



Field Notes of Section marked (d) on the Map.

No. of Station.	Distances in feet.	Heights in feet.
1	0.0	18.4
2	17.6	14.7
3	13.0	8.0
4	10.0	3.1
5	9.0	1.3
6	10.0	5.5
7	5.0	8.3
8	5.0	10.3
9	5.0	15.3
10	10.0	17.3
11	10.0	18.9

Plan of section (d) on a scale of twenty feet to the inch.



Specimen of the Field Notes, August 25, 1841, *commencing at a stake in the middle of a gap, through which the road passes on the east side of the embankment, thence*

1. 138°* 2 ch. 25 links to the centre of a gap, ravine commencing on the outside.
   2 " 69 " to a beech tree.
2. 332° 0 " 96 " to a beech.

* It will be seen that the compass was graduated north-eastward quite round the circle to 360°, hence 138°=south, 42° east.

3. 328½°	0 ch. 62 links	to the centre of a gap.	
	1 " 24 "	to an iron wood.	
4. 267°	1 " 31 "	to a large beech, convex outward ten feet.	
5. 266°	0 " 45 "	to centre of a gap.	
	1 " 45 "	to a sugar tree near a spring.	
	2 " 14 "	to a beech.	

A new Reflecting Level and Goniometer. By Prof. Locke.

This instrument consists of a small spirit level, set in a brass tube, with plane sights, and having a small diagonal reflector placed over the bubble.

It is used without a staff, tripod, or other special support, being raised or lowered by hand, like a pistol, the eye ranging along the sights, until the bubble at the same time seen in the reflector, passes across the central opening, or remains stationary in the field of view, when the range is presumed to be level. In levelling up a hill or ravine, I adopt the following method: Standing at the bottom, and ranging towards the hill, I mark some object, as a stone, a stick, leaf, or a stake, at the horizontal point, of course on a level with the eye. Next, advancing to the above named mark, and standing with my feet upon it, I repeat the same operation with regard to a second mark, &c., keeping tally of the number of observations. In this operation, my own altitude to the eyes, five feet five inches, is the unit of measure, and answers the purpose of the target rod of the engineer. The number of observations multiplied by this altitude in feet, obviously reduces the whole perpendicular altitude to that denomination.

If necessary, I examine geologically each unit, or fathom, by itself, and make a corresponding entry in my note book. In descending a hill, a mark or station may be levelled by back sights, varying the position either backward or forward until the proper altitude shall be attained by trial. This instrument I have found to be peculiarly useful in our thin, horizontal, and varying fossiliferous strata, where at one point we find a seam, say an inch thick, filled with trilobites, at another a similar seam, abounding with entrochites, &c. It is evident, that by two straight strips, the one to be used as a radius, and the other as a *chord*, divided into degrees, we may convert the above instrument into a goniometer for measuring angles either of elevation or of depression. This level is to be adjusted by the usual method of reversal, *but it needs an assistant to observe the bubble in the reverse position.* In observing, the operator may hold the level at arm's end like a pistol, or he may bring one of the sights close to his eye, so as to divide the pupil, according as he finds it most agreeable.

Mr. Davis, No. 11 Cornhill, Boston, will manufacture the reflecting level above described, at the very moderate price of two dollars.

LOCKE'S LEVEL.

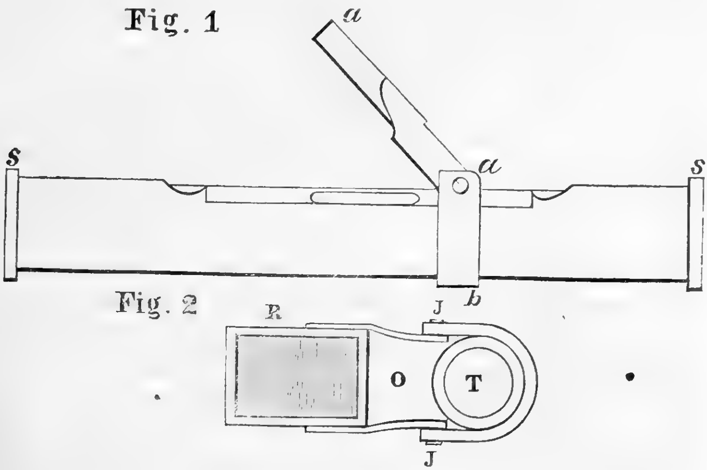


Fig. 1.

s s. A common spirit level.

a a. A reflector.

b. A strip of brass bent round, soldered to the tube, and bearing the pivots *J J*, which permit the reflector to be folded down upon the tube.

Fig. 2. *Front View of the Reflector.*

R. The reflector.

T. The tube of the level.

J J. The pivots.

O. An opening underneath the Reflector.

Notice of a prostrate Forest under the Diluvium of Ohio. By Prof. John Locke.

Fragments of wood, evidently of the tribe of *Coniferæ*, have, at numerous places, been found in the beds of blue clay and gravel, usually considered the diluvial or drift formation of Ohio and the neighboring States. This formation is found along the Ohio river, occupying small local tracts, being generally situated in some depression or chasm in the fossiliferous (Silurian ?) limestone of that region, as at the tunnel of the Whitewater Canal at North Bend, where there seems to have been an ancient gorge, formed, probably, by the Great Miami entering at this point the Ohio river, at a place higher up that stream than at present. But at a point, say sixty miles north of the Ohio, this formation begins to cover the surface to the depth of from thirty to one hundred feet in thickness, giving a peculiar agricultural character to the soil, and forming the grazing district of that neighborhood. At Dayton, Mr. Vancleve showed me a specimen of this wood in superior preservation, which he informed me had been found in digging a well in Salem, a village about fifteen miles to the northward. To this place I immediately repaired, and there learned the following facts: The situation is an elevated one, many miles removed from any considerable stream, thus precluding the idea of any *alluvial* action. At all places in the village, where wells have been sunk, they pass through from thirty-seven to forty-three feet of diluvial clay and gravel, and finally reach the prostrate trunks of the coniferous trees, lying in a bed of dark mud, (a "dirt bed,") below which is a bed of clean sand. As soon as this sand is entered, the water, "welling" up from it to the height of fifteen feet, drives the diggers from their labors. It has, however, been ascertained, that the sand is superimposed upon the cliff limestone in place.*

No roots of the prostrate trees have been found; but still it seems to me, from the extent of the space covered by them, from

* Containing the *Pentamerus oblongus.*

the "dirt bed," and the sand uniformly found beneath it, that the trees have been thrown down in the place where they grew.

The surface soil, for perhaps forty miles in all directions from this locality, is a deep, fertile loam, bearing no cedars or pines, while this ancient surface had a substratum of sand, in which the Coniferæ delight to grow. This, with all the other circumstances, goes to sustain the conclusion, that the formation called the *diluvium* of Ohio, is of comparatively ancient origin, and has, therefore, been correctly named in contradistinction to alluvium, which implies the agency of the present streams. Some circumstances indicate that the remains of the mastodon are cotemporaneous with this formation. Mr. Lyell is now attempting to solve the problem of the geological age of these fossils. The above circumstances may possibly aid in the interesting research.

On some Pseudomorphous Minerals of the State of New York. By Lewis C. Beck, M. D., *Professor of Chemistry and Natural History in Rutgers College, New Jersey.*

The terms *pseudomorphous* and *metamorphous* have been applied to those minerals which possess a crystalline form that is foreign to them; and which they have received from some cause entirely distinct from their own powers of crystallization. Haidinger, however, has more appropriately, and perhaps more definitely, applied to such formations the term *parasitic*, which denotes the intrusive nature of the new compounds in prejudice of those which existed before.

The most extended notice of this curious subject which I have met with, is that published by Haidinger, in the ninth and tenth volumes of Brewster's Edinburgh Journal of Science, (1828 and 1829.) Since that time I am not aware that much has been done in the way of collecting facts, nor that any attempt has been made at generalization. But when it is borne in mind that the changes which are here referred to, do not take place in small and rarely found crystals only, but are sometimes exhibited in extensive rock formations, the importance of the subject to the mineralogist and geologist, will at once be apparent. For if the chemical composition of a mineral may be partly or wholly changed while the external form remains the same, the observer who is inattentive to these facts may often be led into mistakes.

The object of this communication is to present some facts in regard to the parasitic formation of mineral species which I have observed in the State of New York, and to offer some suggestions of a general nature.

Changes in Minerals containing Baryta.

Haidinger has alluded to a change which takes place in the *baryto-calcite*, a mineral containing one atom of carbonate of lime and one atom of carbonate of baryta, namely, its conversion into heavy spar, while the form of the original mineral remains. He thinks that "sulphuric acid and water must have acted jointly to effect this change, but the decomposition must have proceeded slowly. The carbonic acid is expelled by the former, and the latter will carry away the sulphate of lime which is thus formed, leaving only the sulphate of baryta."

In the county of Schoharie there are minerals containing baryta, strontia and lime, which appear to have undergone a variety of changes. Thus in the town of Carlisle there occurs a fibrous mineral in veins between the layers of argillaceous slate, which is now a pure sulphate of baryta with a specific gravity of from 4.014 to 4.030, and then as pure a carbonate of lime with a specific gravity not above 2.737. And between these two extremes there are mixtures of the two minerals in almost every variety of proportion. It is probable that these have originally been the same mineral; but in what manner the change has been effected, I am not able at present to determine.

In other parts of this county, and especially at the village of

Schoharie, the sulphate of baryta often has admixtures of carbonate of strontia and carbonate of lime, and several new species have been proposed, in which differences in chemical composition are chiefly relied on as distinctive characters. Such are believed to be the *Calstron-baryte* of Shepard, and the *Emmonsite* of Thomson. I have also analyzed a mineral from that locality, which has the same, or nearly the same crystalline form as sulphate of baryta, but which is a mixture of the sulphates of strontia and baryta, with twelve or thirteen per cent. of carbonate of lime. There seems to be here a series of replacements and mixtures, which renders it extremely hazardous to propose new species from mere differences in chemical composition.

Changes in Minerals containing Magnesia.

In Phillipstown, in the county of Putnam, there is a bed of white limestone, which contains serpentine in considerable abundance. This mineral here presents several varieties, which may be traced to foreign admixture. One variety has a conchoidal fracture, exhibits various shades of green and yellow, and is found in small rounded masses. Another has a dark green color, is very hard and compact, has a slaty structure, and sometimes breaks into rhomboidal prisms. A third variety is also slaty, has a greenish white color, is harder than either of the preceding, and is fusible upon thin edges, by the blow-pipe. It is evident, from an inspection of the locality, that all these belong to the same species, and yet, in hand specimens, they might well be considered as distinct. The slaty and altered appearances which the serpentine exhibits, is due to the admixture of pyroxene or tremolite, or both, minerals which are here found in sufficient abundance.

I may also add in this place, that from an attentive examination of numerous localities, I have little doubt of the identity of the several minerals, which have passed under the names of marmolite, kerolite, magnesite, retinalite, and Deweylite. They are all serpentine, more or less altered by the intrusion of foreign substances. The marmolite of Hoboken and Staten

Island is little different in composition from true serpentine. The mineral from Stony Point, and which has been referred to kerolite, differs from serpentine in containing ten or twelve per cent. of oxide of iron, a circumstance which I attribute to its being associated with a hornblendic rock. In the case of Dr. Thomson's retinalite, the replacement of the soda for magnesia, may on examination prove to be referrible to some accompanying mineral.

It is perhaps almost unnecessary to state, that the hydrate of magnesia is constantly undergoing change in consequence of its combination with carbonic acid. The most striking exhibition of this fact that I have observed, is in the town of Rye, in the county of Westchester, where veins of hydrate of magnesia are frequently invested with a white crust or powder of the carbonate. Indeed, a similar change takes place in the cabinet.

Changes in Hornblendic Materials.

In the town of Warwick, in Orange county, there occur in magnesian limestone crystals of a gray color, having the form and cleavage of hornblende. These crystals are sometimes bent as if they had been fused, but they are sometimes very perfect, and admit of measurement by the common goniometer. They are peculiar, however, in having a soapy feel like steatite, and they are often so soft that they can be easily cut with a knife.

An analysis of one of these crystals gave the following results, in one hundred parts, namely:

Silica,	35.00
Alumina,	32.33
Lime,	10.80
Magnesia,	20.70
Water,	1.17

The principal difference in chemical composition between this mineral and the several varieties of hornblende, is in the larger amount of alumina, which has, in part, replaced the silica. In a specimen of white tremolite, Bondsdorf found sixty parts of silica, twenty-four of magnesia, and nearly fourteen of alumina. The larger proportion of alumina in this and other cases is ascribed by Beudant to the substances which are associated with the hornblende, as spinelle, Wernerite, &c.

The limestone which contains this soft hornblende is not, I believe, remarkable for the abundance of spinelle, but a variety of mica is disseminated through it, which is very rich in alumina.

These crystals have been ticketed pyroxene, zoizite, and lastly, kerolite pseudomorphous of hornblende. The crystalline form, however, is totally distinct from either of the two former, and its chemical composition must remove it entirely from the latter. It is most probably hornblende altered by an intrusion of alumina and the removal of a part of the silica. The contorted and somewhat fused appearance of many of the crystals clearly point to heat as the general agent by which these changes have been produced. And as granular condrodite and fluor spar are disseminated through the same limestone, may not the condrodite have been formed by the combination of the silica, which these crystals have lost, with the magnesia and the fluor, by the decomposition of the mica?

Grayish-green Mineral.

In the same town, and in the same limestone, there are crystals of a grayish-green color, and having the form of long oblique rhombic prisms, with the angles of hornblende.

The hardness of these crystals scarcely exceeds that of talc. They are sometimes slightly translucent. The powder is white. The following are the results of my analysis of a fragment of one of the most perfect crystals, namely:

Silica,	34.66
Alumina,	25.33
Lime,	5.09
Magnesia,	25.22
Water,	9.09

In this case, therefore, there is a little less lime and more magnesia than in the preceding. The proportion of alumina is also less, which is made up by water.

The nature of the changes which have taken place in this mineral, and the causes which have operated to effect them, are probably similar to those just noticed.

Changes in Spinelle.

There is in Orange county a mineral which has long been known, and which has also passed under various names, as kerolite pseudomorphous of spinelle, pseudolite, &c. These names seem to have been employed to express the supposed chemical constitution and the crystalline form.

The crystals to which I refer are of a black color, and of an octahedral form, exactly resembling those of spinelle. They are imbedded in a gangue of soft, dark-colored serpentine. These octahedrons can be scratched with a knife, and easily reduced to a coarse powder; but the powder, which is of a gray color, is gritty, and with difficulty rendered impalpable.

In conducting the analysis of this mineral, I found that a good part of the powder operated on, resisted two or three fusions with carbonate of soda. This led me to suspect that it might contain a portion of real spinelle, instead of its being, as I had supposed, entirely made up of serpentine or some allied mineral. The correctness of this view was confirmed by my subsequent examinations.

The composition of these crystals is nearly as follows, namely:

Silica,	19.07
Alumina,	35.00
Oxide of iron,	9.97
Magnesia,	28.58
Water,	7.33

If now we take about seventeen parts of the silica, fifteen of magnesia, six of water, and two of oxide of iron, they will produce about forty per cent. of serpentine, and the remaining constituents will be nearly in the proportion in which they are found, according to the most trustworthy analyses, to occur in spinelle.

The peculiarity of this mineral, therefore, is to be referred to the intrusion of the serpentine into the crystals of spinelle, a part of which has been removed. And although the crystals are softer than we might suppose them to be from their composition as above stated, it is quite probable that during the process of substitution the cohesion of all the particles has been impaired so as to bring about the apparent softness of the crystals, while the particles are really so hard as they prove to be when subjected to the action of the pestle.

Changes in Pyroxenic Minerals.

The changes about to be noticed are of an equally striking character with those already described, but they often occur upon a much larger scale, so much so that they are exhibited in rocky deposits of considerable extent.

The first example to which I shall here refer is the mineral substance, or rock, which has been called by Dr. Emmons *Rensselaerite*, but which, for reasons to be presently given, I denominate *steatitic-pyroxene.*

The description given by Dr. Emmons is as follows:

Hardness=3.5 to 4.0. Specific gravity, 2.874. Form, oblique rhombic prism M on M=94° and 86°; P on M=106° 30′: (these are not, however, by any means constant.) Color various, sometimes white or yellowish-white, but often dark. Fracture uneven. Before the blow-pipe it fuses with difficulty into a white enamel.

According to my analysis, the composition of a specimen from Canton, in St. Lawrence county, furnished me by Dr. Emmons, is as follows, namely:

Silica,	59.75
Magnesia,	32.90
Lime,	1.00
Peroxide of iron,	3.40
Water,	2.85

The above results differ from those afforded by most of the pyroxenes in the greater proportion of magnesia, which replaces lime, and is isomorphous with it, and in a little excess of silica. They are, however, quite similar to those obtained from the steatitic pyroxenes of Sahla, noticed by Beudant. These compounds are described as containing variable proportions of foreign matter, but still having the form and cleavage of pyroxene. This author quotes three analyses by Rose, one of which is as follows, namely:

Silica,	60.65
Lime,	4.97
Magnesia,	25.20
Protoxide of iron,	4.18
Oxide of manganese,	0.78
Water,	4.38

According to calculation, this contains pyroxene, 37.40, steatite, 62.30, hygrometric water, 0.40.

The localities of this altered mineral are so numerous in the counties of St. Lawrence, Jefferson, and Lewis, and they are of such considerable extent, that the cause which operated to produce the change must have been a general as well as a powerful one. An examination of the beds of white limestone in which the altered masses are found, sufficiently attests the agency of heat. Nodules and semi-crystalline forms of serpentine every where occur, together with hexahedral scales of graphite. And the crystals of phosphate of lime, quartz, scapolite, and of other minerals, constantly exhibit that rounded form, which we at once ascribe to fusion at the moment of, or subsequently to, their formation. Now the heat necessary for the fusion of quartz would easily effect the liquefaction of pyroxene. And if in this lava-state the materials of serpentine were injected into this mineral, it would produce a change similar to that which is now observed in the steatitic pyroxene.

Before this explanation can be received, however, an important question is to be decided. It is this: whether the presence of one mineral substance, especially if it be not peculiarly susceptible of crystallization, changes the crystalline form of another mineral? In some cases I am aware that very small proportions of one salt will change the crystalline form of another salt; as where sulphate of iron crystallizing in a solution of alum, takes the octahedral form of the alum, although the crystals contain scarcely a trace of this salt. I am also aware, that certain bodies, when they exist together in solution, may, in a striking manner, modify each other's form; as for example, when carbonate of lime and carbonate of magnesia are found mixed together, as in dolomite, the angle of the rhomb is intermediate between that of the two simple carbonates. These, and many other interesting facts, have been well explained by the recent investigations of the subject of isomorphism. But in order to account for the facts just adverted to, it is necessary that we should admit that foreign substances, not known to be isomorphous, may be introduced either during the process of crystallization or subsequently to its completion, without materially changing the form of the crystal. Do not the facts which I have already presented, besides many others known to chemists and mineralogists, warrant this conclusion? And if they do, we have at least taken one step towards a theory of these changes.

There are one or two examples in confirmation of the above views, too striking to be omitted. It is well known that many of the beautiful and perfect crystals of quartz found at Little Falls and Middleville, in Herkimer county, have masses of anthracite diffused through them. In some instances, indeed, they are so copiously studded with minute particles of this substance as to give the crystals a black color. I have also observed that the cavities in the calciferous rocks which contain these crystals are lined with the same black powder.

The dodecahedral crystals of quartz, which are associated with iron ore, in St. Lawrence county, often have a porous or spongy texture, with a considerable mixture of oxide of iron, while their form remains unaltered.

Another instance of a similar kind will be found in some foliated or semi-crystalline specimens of Kyanite, in which thin plates of mica are constantly interposed, between the folia of the mineral, without having in the least interfered with its crystalline arrangement. Now we have only to extend these facts to afford an explanation of the phenomena observed in the hornblendic and pyroxenic minerals which have been described. Thus the hornblende, the spinelle or the pyroxene, may retain its crystalline form, perhaps in a skeleton state, while foreign substances, as alumina, or serpentine, or steatite, are intruded.

Changes in the Minerals found in the Dolomitic Limestone.

The minerals which occur in the dolomitic limestones of New York, Westchester and Putnam counties, every where afford the evidence that their chemical composition has been influenced by the nature of their associates. The following are some of the changes which I have observed.

1. The crystals of white pyroxene which abound in it, frequently have a granular texture like the dolomite itself. Sometimes parts of the crystals have disappeared, apparently by the crumbling of the granular material, which has wholly or in part replaced the pyroxenic matter. Yet the crystalline form is entirely preserved. Examples of this kind may be seen at Sing-Sing, Kingsbridge, and at Patterson in Putnam county.

2. This dolomite often contains a substance with the cleavage of pyroxene, but which is soft and has a large admixture of carbonates of lime and magnesia. The external characters strongly resemble those of some specimens of pyroxene, but the effervescence which is exhibited when it is acted on by a dilute acid shows that it is largely mixed with carbonates.

3. The white tremolite, which is also one of the minerals found in this dolomite, exhibits changes similar to those which have been described as applicable to the pyroxene.

4. As it regards serpentine, the mixtures of its different varieties with the dolomite and with the pyroxene, would, if reliance was placed merely upon chemical composition, furnish many new and distinct mineral species.

I do not assert that these changes are produced by heat, which seems at the present day to be marshalled up on all occasions as the grand geological agent, but it seems to me that they more nearly resemble those which are known to be caused by heat than those which are the result of any other agency. This view too would entirely accord with the ingenious theory of dolomitisation proposed by Von Buch, and which is confirmed by many other facts connected with the occurrence of dolomitic beds in the southern part of New York. Among these I may here mention the fact that in the gneiss which abuts upon this dolomite there are crystals of epidote, stilbite, apophyllite, mesotype, and other minerals quite peculiar to rocks of igneous origin. I have also found analcime in well defined leucite crystals, together with a great abundance of rounded trapezoidal crystals of garnet in the gneiss at Yonkers, in Westchester county, which is also associated with the dolomitic deposit.

Changes in the Ores of Iron.

It not unfrequently happens in the northern part of New York, that beds or parts of beds or veins are alternately made up of the magnetic iron ore and the specular ore. This is particularly observable in the Arnold mine in Clinton county, where the ore in one of the veins, although it has the structure and all the external characters of the magnetic oxide, gives a red powder, and upon analysis is found to be the peroxide of iron. In the Saxe mine, at Crown Point, the ore, which seems to have been originally magnetic, has been changed to the peroxide, and indeed in this case the structure is fibrous, exactly resembling that of the Limonite of mineralogists. More partial changes of a similar kind occur in many of the deposits of iron ore in other parts of Essex county, as at the Everest and Green mine, where the magnetic passes into the specular or red ore in various parts of the vein or bed.

Changes similar to the preceding have been noticed by Haidinger. In the papers already referred to, he describes "the octahedral crystals from Brazil, often of considerable magnitude, and of a particular ore of iron. They afford a red streak, and seem to contradict the characteristic of Mohs, namely, that it should have a black streak. On a more close inspection, however, the octahedral masses are found to be composed of a great number of small crystals resembling those of the rhombohedral iron ore, a species, one of whose characters is in fact the red streak observed. A specimen from Liberia given to Mr. Allan by Sir A. Crichton, presents the same change, excepting that in this specimen the individuals of the rhombohedral iron ore are so minute that they form a compact mass, contained within smooth planes, having the situation of the faces of a regular octahedron."

Now the change from the magnetic oxide to the specular ore is a very slight one, the former containing one atom of protoxide of iron and two atoms of peroxide, while the latter is the pure peroxide. Still, although the only difference between these two minerals consists merely in two or three per cent. of oxygen, it is not so easy to account for the change. Whence has the oxygen been obtained by which it was effected? I would suggest whether the protoxide of iron may not have been replaced by some other substance, as lime or magnesia, which has in its turn again been dissolved out.

To the changes which have thus been noticed, I will only add that which has taken place in some of the strata of red marl in the vicinity of the salines of Onondaga county. There are often observed in these strata hopper-form cavities and crystals, consisting of the material of the clay covered with an incrustation of calcareous spar, resembling those crystals of salt formed during an intermission in the application of heat, and commonly known by the name of *Sunday salt.* About half a mile from the village of Camillus, on the route of the Auburn and Syracuse rail-road, the marly clay is chiefly made up of these crystals, varying in size from one inch to eight inches. They usually have their surfaces covered with an incrustation of pure carbonate of lime, and their bases slightly rhomboidal and variously bent. They indeed appear as if subsequently to their formation, they had been subjected to a highly elevated temperature. I analyzed a fragment of one of these crystals and found its composition to be as follows, namely:

Carbonate of lime,	26.25
Carbonate of magnesia,	19.35
Oxide of iron,	4.65
Silica and alumina, (clay,)	49.75

From the form of these clay crystals it has been inferred that they were originally crystals of salt. Now whether these were dissolved out by water, and the new material introduced by the same agent or not, I still think it probable that they have been afterwards subjected to heat. This seems to have been necessary to give them the peculiar appearance which they now exhibit.

Such are the facts which I have observed in regard to the parasitic formation of minerals in the state of New York. The following are some of the inferences which seem to me to be fairly deducible from them.

1. Many crystalline minerals have undergone changes in their chemical composition subsequently to the period of their crystallization. The changes which have taken place in crystals of quartz, and magnetic iron ore, may be referred to as examples.

2. The foreign bodies which must have been associated with some minerals at the moment of crystallization, have not in the least degree interfered with the regularity and beauty of the crystalline form. This inference is supported by the facts in regard to the masses of anthracite found in the most perfect quartz crystals of Herkimer county, &c.

3. The probable intrusion of foreign matter into the substance of crystals, after a portion of the original constituents of these crystals has been removed, without any change of crystalline form, and that too without reference to the isomorphous relations of the removed and the replacing bodies. Under this head I may refer to the notices which I have introduced of the changes in the hornblendic and pyroxenic minerals, &c.

4. In regard to the general agency by which these changes have been produced, it seems to me to be fairly deducible from a review of all the facts which have been presented, that although aqueous solution may in some instances have been the means of removing some of the constituents of the altered mineral, the intrusion has been the result of igneous action. The bent crystals of the grayish hornblende, the fused appearance of the crystals of quartz and apatite in the county of St. Lawrence, near the deposites of steatitic pyroxene, and the occurrence of various volcanic products in the vicinity of the altered minerals of the dolomite of Putnam, Westchester and New York, may be adduced as proofs of the correctness of this inference.

Description of five new Species of Fossil Footmarks, from the Red Sandstone of the Valley of Connecticut River. By Edward Hitchcock, LL. D., *Professor of Chemistry and Natural History in Amherst College, Mass.*

Since the publication of my Final Report on the Geology of Massachusetts, in which I described twenty-seven species of fossil footmarks, I have not been able to prosecute inquiries on the subject to much extent; and therefore, with one exception, the new species described in this paper, have been made out from specimens presented to me by Dr. James Deane, who obtained them at Turner's Falls on Connecticut river, between the towns of Gill and Montague, and at the Horse Race, a few miles further up the stream.

When I made out the species for my Report, I had little doubt that several were included under the name of *Ornithoidichnites tuberosus:* but I could not well define the distinctions between them. An examination of better specimens enables me to separate at least one species.

In my Report I have given three figures of O. *tuberosus:* namely, Plate 37, figs. 20 and 21, and Plate 38, fig. 22. A moment's inspection of these figures shows a striking difference between fig. 20 of Plate 37, and the other two figures. But as the former was destitute of claws, I thought it safest not to separate it from the others. Having since, however, found the claws upon numerous specimens, I shall describe this variety as the O. *tuberosus;* excluding the other figures above referred to.

I stated in my Report, that in most of the Pachydactyli, the tuberose swellings, or muscular impressions of the foot, are two on the inner toe, and three on the middle toe; but that I had no distinct example in which there were four on the outer toe; though I had no doubt that such was always the case. I have since seen numerous examples, some of the most distinct of which were obtained by Dr. Deane. I am now, therefore, prepared to give a corrected description of O. *tuberosus;* limiting that species to

Plate 37, figure 20 of my Report; which ought, perhaps, to have been re-drawn from a more perfect specimen for this paper. But I am anxious to make my sketches as few as possible.

Ornithoidichnites tuberosus. Toes three in front, straight, spreading forty degrees: tuberous swellings remarkably distinct and broad: two on the inner or shorter toe; three on the middle toe, and four on the outer toe. Claws distinct, acuminate, from an inch to an inch and a half long. Middle toe extending nearly three inches further forward than the lateral ones. Length of the middle toe, (reckoning from the posterior extremity of the tuberous swellings to the extremity of the claw,) five to six inches. Length of the foot, seven to nine inches. Length of the step, twenty-five to thirty-three inches.

This species occurs in the greatest abundance at Turner's Falls and the south part of Northampton; but it is found at almost every locality of footmarks in the valley of the Connecticut, and recently, (December, 1842,) it has been discovered by William C. Redfield Esq. in the red sandstone of New Jersey, at Pompton, in connection with the impressions of rain drops. This is the first time a fossil footmark has been found in this country out of the valley of Connecticut river. The fact is, therefore, of great interest. Although the middle toe of the specimen was broken off, yet the tubercular swellings on the lateral toes, and their claws, were remarkably distinct, and could not have been mistaken by one so familiar with footmarks as Mr. Redfield.

The variety of O. *tuberosus* of my Report which has now been described, differs so much from the other varieties given in Plate 37, figure 21, and Plate 38, figure 22, that I hesitate not to describe the latter as a distinct species. They differ from the O. *tuberosus*, chiefly in being in every respect more slender and delicate; a distinction which it is not easy to make in a description, though obvious to inspection. This new species, which I found upon the above figures of my Report, I propose to denominate O. *Sillimani*, as a testimony of my respect for the character and the valuable and long continued labors of Professor Silliman in the cause of science. Its description is as follows:

*Ornithoidichnites Sillimani.** Toes three, all in front; spreading from thirty to forty degrees: tuberous expansions usually distinct: two on the inner toe: three on the middle toe; and four on the outer toe. Claws very distinct, an inch long. Length of the middle toe, five inches: of the whole foot, six to seven inches: of the step, eighteen to twenty inches. The whole foot more slender and delicate in its proportions than the O. *tuberosus.*

Pl. XI, fig. 2 shows two small tracks of O. *Sillimani* in relief, from Turner's Falls: the specimen being in the possession of Dr. Deane. The track is considerably smaller than this species usually is, and some parts of the toes are wanting: but other parts are remarkably distinct. It would seem that these tracks were made by the animal when standing still: and I have given a drawing of them for this reason; because it is nearly a solitary example of such a position of the feet.

The O. *Sillimani* is found at most of the localities of footmarks in this valley.

The second new species which I have to describe, is a small *Leptodactylous* track, from the Horse Race in Gill, three miles higher up the river than Turner's Falls, and long known as a fine locality of footmarks. I dedicate it to my friend, Prof. Henry D. Rogers of the University of Pennsylvania; whose able and successful labors as a geologist, eminently entitle him to such a mark of respect. The following is a description of the species.

Ornithoidichnites Rogersi. Toes four, three of them in front: the lateral ones spreading about seventy-five degrees: length of the middle toe, seven eighths of an inch. Hind toe nearly on a line with the outer one; seven eighths of an inch long. Entire length of the foot, including the hind toe, one inch and three quarters. Length of the step, from three to four inches. Shown of the natural size on Pl. XI, fig. 7.

This species approaches the O. *gracilior* of my Report. But it is much smaller, and the hind toe is a good deal longer in pro-

* I am aware that in such a case as that in the text, the best rules require the name of the individual to be expressed adjectively. But for reasons that cannot here be given, I prefer the genitive form; and I believe this is not without abundant authority.

portion to the others than in O. *gracilior*. It occurs on the gray micaceous slate of the Horse Race.

Last winter, (1842,) I took the sketch of the track of a *snow bird* (*Fringilla Hudsonia*, I believe,) on snow, and on discovering the O. *Rogersi*, I was struck with the resemblance between them. This will be obvious by comparing figs. 7 and 8; both of the natural size. The latter, however, is more delicate, and the hind toe points somewhat more directly backwards than in the fossil track. Nevertheless, it would be easy to imagine that the same species of animal made them both.

All the species of Ornithoidichnites which I have hitherto described, I have been able to bring under two general divisions; the LEPTODACTYLI, or *slender-toed*, and the PACHYDACTYLI, or *thick-toed.* But the two next species, which I have to propose, appear to me to belong to neither of these divisions; and to require a new term to express their general character. I propose to call them PTERODACTYLI, or *wing-toed;* because they appear to have been made by an animal, which, like the coot and the grebe, had a membrane, with an indented margin, extending along its toes. The first species, which I shall describe, might easily be mistaken for the O. *tuberosus*, when upon a surface where the impression of the membrane would not be noticed. But in the very perfect specimens which I possess, that impression is perfectly distinct; especially around the claws; and the bottom of the foot is sunk but very slightly into the mud; so that it is perfectly distinct from the tuberosus, and is a most beautiful track. I take the liberty to derive its specific name from that of Charles Lyell, Esq. of London: not to make him better known, but as a tribute of respect for his eminent services in the cause of geology; and as commemorative of the pleasure I recently experienced in conducting him to some of the localities of our fossil footmarks. The characters of the species are the following:

Ornithoidichnites Lyellii. Toes three, all in front: straight, spreading forty degrees: curved expansions on the inner toe, two: on the middle toe, three: on the outer toe, four: all remarkably distinct, and making but a shallow impression: indicating a foot nearly flat on the under side. Claws from an inch to an inch and a half long; showing along the whole length, the impression of a rounded web or membrane; which did not sink as deep as the claw. Middle toe extending three inches beyond the lateral toes. Length of the middle toe, five or six inches. Length of the foot, seven to nine inches. Length of the step, undetermined.

The sketch of this track given on Pl. XI, f. 1, of the natural size, was taken from two specimens of almost exactly the same size. One of them exhibited all the track perfectly, except the middle toe; which was supplied from the other. Both were obtained from Turner's Falls.

The second species of Pterodactyli was from the same locality; and on several accounts possesses a good deal of interest. From its resemblance to the foot of the Cinereous Coot, (*Fulica Americana*,) I have denominated it *Ornithoidichnites fulicoides*. Its characters are as follows:

Ornithoidichnites fulicoides. Toes three, all in front, spreading eighty degrees: the middle one extending one inch and a quarter further forward than the lateral ones. Tuberous swellings, two on the inner toe, three on the middle toe, and four on the outer toe; very distinct. Impression of a curved fleshy membrane on all the claws: the nail making a depression in the middle, and deeper than any other part of the foot. Length of the middle toe, two and a half inches: of the foot, four inches: of the step, from eight to ten and a quarter inches. Shown of the natural size in Pl. XI, f. 3. The part colored darker near the extremity, shows the deeper impression made by the claw.

This species differs from O. *Lyellii* in two decided characters: first, in being twice as divaricate: secondly, in the much less extension of the middle toe beyond the others. It is, also, much smaller. It differs from the O. *expansus* of my Report, in the impression of a membrane around the claw. If it should be found that the O. *cuneatus* of Dr. Barratt has such an impression, it could hardly be separated from the O. *fulicoides*. But my specimens of the O. *cuneatus* are not distinct enough to settle this question: yet Dr. Barratt's representations would lead to the conclusion that no such membranous impression exists. I strongly suspect that the row of tracks figured on Plate 48, figure 55, of my Report, from a specimen in my cabinet, which I have refered to O. *cuneatus*, belongs to the O. *fulicoides;* but the extremity of the toes has been very much effaced.

Pl. XI, f. 4 exhibits a slab of this species which was originally in the cabinet of Dr. Deane. But he has kindly divided it in order that one row of these tracks should be placed in my collection: and I am sorry to learn from him that his portion of the slab has been accidentally destroyed. On two accounts, it is one of the most interesting exhibitions of tracks which I have ever seen. In the first place, these tracks all exhibit the tuberous expansions, as has been described, namely, two on the inner toe, three on the middle, and four on the outer toe, besides that connected with the claw; and it can be seen most distinctly how the right and left foot succeed each other in regular order. In the second place, on the right hand side of the drawing, two rows of tracks are seen almost exactly on the same line, and situated with respect to each other precisely like those of some quadrupeds; even when the animal appears to have somewhat changed his course; though we cannot be sure that such was the fact, because we cannot see the succeeding track; and this animal appears to have stepped wider than usual. Yet the row of tracks on the other side of the slab, is obviously single; that is, made by a biped. The presumption, therefore, is, rather that the same animal walked twice along the same line, or that one followed another. I have pointed out an analogous case as occurring in Wethersfield, Connecticut, in Plate 32, figure 10, of my Report. And such cases should be kept in mind; as they may lead ultimately to important results. What a pity, in the present instance, that a larger surface could not have been examined, than this slab presents.

Having been permitted to examine the feet of the Cinereous Coot, (*Fulica Americana*,) in the cabinet of the Boston Natural History Society, I was much struck with the almost exact resemblance between their indented margin and the tracks of O. *Lyellii* and *fulicoides* just described. The number of these expansions on the different toes, corresponds exactly with those upon the tracks, as may be seen on Pl. XI, f. 6, which is the outline of the coot's foot. The coot's foot, also, is flat on the bottom; and such appears to have been the case with the foot that made these tracks; especially the O. *Lyellii;* for the O. *fulicoides* is more rounded at the bottom.

The sketch, Fig. 6, will show that the claw of the coot's foot is free from an attached membrane, and in this respect it differs from the tracks under consideration. In the *Pied-bill Dob-chick*, however, (*Podiceps Carolinensis*,) the membrane extends to the end of the claw; as may be seen on the sketch Pl. XI, f. 5, which is copied from a dried specimen in the Cabinet of the Boston Natural History Society. The same may be seen in some of the figures of the feet of the Linnean genus Colymbus, in Rees' Cyclopedia, Plate III of Ornithology; where also may be seen outlines of the feet of the Tringæ and Fulicæ, corresponding to Fig. 6.

Figs. 6 and 5, are of the natural size: and for them I am indebted to Dr. S. L. Abbot, Jr. of Boston. Fig. 6 shows the right foot of the coot, and Fig. 5, the left foot of the dob-chick. Dr. Abbot adds: " In the last, the hind toe may occasionally touch the ground; and its extent is, therefore, given. In the first, the hind toe rests on the ground; and the length of its impression in walking, would vary with the length of the step, as it is articulated on the tarsus above the other toes."

It is difficult to compare the tracks on stone above described, with the feet of such birds as the coot, the tringæ, and the dob-chick, without feeling that both must belong to the same class of animals: and that the one must be a type of the other. I mean, if we make the feet of living animals the standard of comparison. That there may have been animals in the red sandstone period, of a different class, say reptiles, with feet so exactly like our present birds, as some of the tracks on stone seem to be, it is easy to imagine: especially when we learn that there was at least one extinct reptile, (the pterodactyle,) that walked on two feet. But when we come to examine the feet of all the species of that animal hitherto discovered, we find them with four or five toes pointing forward. We are then left almost to conjecture to sustain the opinion that other biped saurians once existed with feet so nearly agreeing with those of birds. While, then, it seems to me unphilosophical, in the face of all living analogies, to assert in respect to many of the tracks on stone, that they are not those of birds; it would be contrary to the cautious spirit of science on the other hand, to decide that they are certainly such. I have endeavored to take a middle course, by naming in my Final Report, some of these tracks, *Ornithoidichnites*, or tracks *resembling* those of birds, and others, *Sauroidichnites*, or tracks *resembling* those of Saurians. Living analogies lead us to conclude that most of them are the tracks of birds: but there is plausibility enough in the opposite conjecture, to justify the use of terms that imply resemblance rather than actual identity.

New Species of Sauroidichnites.

I dedicate this species to my esteemed friend, Rev. Chester Dewey, of Rochester, New York; whose "Caricography" alone would entitle him to such a notice, were it necessary to select a single production from the labors of a whole life devoted to science.

Sauroidichnites Deweyi. Toes four, all directed forward: the inner toe, or thumb, very short: the three outer toes lying nearly parallel; all of them thick, and having claws more or less distinct: the outer ones spreading only ten degrees. Impression made by the claws deeper than any other part of the foot. Alternate tracks smaller. Length of the largest track one and a quarter inch: of the smaller, three quarters of an inch. Length of the step, three and a half inches. Shown of the natural size on Pl. XI, f. 9, copied from the only specimen I have seen.

It will be seen that the specimen shown on Fig. 9, bears a stronger resemblance to the tracks of the Cheirotherium of Europe, than any example which I have ever found in this country. The specimen is so small, that we cannot, indeed, be sure that the larger and smaller tracks succeed one another alternately; especially as the larger ones point in directions so diverse. Yet I incline to the opinion that the animal changed its course at this point, and that the tracks are indeed in succession. This is rendered more probable by the occurrence of a larger and smaller track having the same relative position upon another part of the specimen. The probability, therefore, is, that this is the track of a quadruped. Indeed, its appearance is like the track of a four-footed animal. Yet it differs from the Cheirotherium in having only three toes besides the thumb. Still the shape of the toes corresponds well to those of the Cheirotherium.

If I am not mistaken, then, this is the first example in which I have any certain evidence that any of the numerous tracks upon the sandstone of the Connecticut valley were made by a quadruped: though, as will be seen by reference to my Final Report, I strongly suspected such might be the case in respect to several of them. There is another interesting fact shown by the specimen under consideration. Its surface has that pitted appearance which was probably the result of rain drops. The tracks were evidently made afterwards. We hence learn that the surface was above the waters at the time both the impressions were produced. But it must have been subsequently submerged to bring over it another layer of mud.

There is a close approach, in the track I have now described, to the Ornithoidichnites *parvulus* of my Report; except that the latter has only three toes. But as I possess only a single specimen of O. *parvulus*, and that considerably worn, it would not be strange if both these species should prove to be identical. But until a fourth toe shall be discovered on the O. *parvulus*, we can hardly make of it a Sauroidichnites.

Dr. Deane has recently discovered a new locality of *Ornithoidichnites giganteus*, in the northeast part of Deerfield, at a small quarry half a mile south of the bridge over Connecticut river. He finds, also, fine examples of rain drops at Turner's Falls. I have discovered the same at the localities of footmarks in Montague and Northampton. I would state, also, that I have lately noticed several cases of the impressions of rain drops on mud, after a shower, exactly resembling those on stone, and produced in the following manner. During the shower, fine mud was carried into depressions of the surface, from which the water soon escaped; and near the close of the shower, a few large drops of rain fell, as is often the case, and produced the pitted appearance of the mud. The striking resemblance between the mud thus impressed, and the surface of the sandstone showing rain drops, renders it quite probable that the latter were produced in a manner similar to the former. I would, also, refer to a common brick kiln, for an illustration of this subject. After the bricks are moulded, rain sometimes falls upon them before they are burnt; in which case, after burning, their surface appears like the fossil rain drops almost precisely. I have noticed, likewise, upon burnt bricks, impressions of the human foot, or hand, made before burning, which were as perfect as the fossil footmarks. Such facts help to remove our difficulties as to the manner in which the impressions of rain drops and footmarks might have been preserved.

Half a mile west of the prolific locality of footmarks in the southeast part of Northampton, and at an elevation of more than one hundred feet above Connecticut river, I noticed several specimens of O. *elegans*, on the red micaceous sandstone: and should a quarry be opened there, it could hardly fail to furnish specimens equal to those from Wethersfield.

I lately succeeded in uncovering a surface of gray fine micaceous sandstone, at the locality first named above, on which were exhibited seven continuous tracks of the *Ornithoidichnites giganteus.* The right and left foot are shown most strikingly; and it is hardly possible for the beholder to doubt that they were produced by a biped animal walking over the surface with strides from three to four feet long. I was able to raise a slab, fourteen feet long, containing four of these tracks, and had it conveyed to the Cabinet of Amherst College; where it forms the most striking specimen of footmarks in my possession. I hope soon to add the other three; so that the whole seven shall again be exhibited in the same position as in the quarry.

Dr. S. L. Dana has recently presented me with some deposits of copper, prepared by him in electrotype processes, which beautifully illustrate the manner in which the mud, on which animals had trod, retained the impressions of the tracks through several successive layers upwards. Even the finest marks upon the original, of which a copy is to be taken, are exhibited through a considerable thickness of the deposited copper, as an examination of the specimens will show: so that if successive layers could be cleared off, we should have so many engraved plates. Just so, when we actually cleave off the layers of rock, once mud, lying above that layer on which the track was originally made, we get a track upon each layer; the successive tracks upward, however, becoming less and less perfect, until in the vertical distance of one or two inches, often less, they are entirely filled up. The vertical distance through which an impression may be continued in plastic materials, will depend upon the degree of plasticity, and the rapidity with which they harden. Hence, as copper is entirely dissolved until the moment of deposition, and is then instantly made solid, we should expect it to exhibit this effect in an eminent degree, much more so than mud. And the specimens before us fully confirm this expectation. They are, therefore, valuable in illustrating a point which has been a stumbling block to some in respect to fossil footmarks.

On the Polished Rocks of Rochester, N. Y. By Rev. Chester Dewey, *of Rochester.*

The "Glacial Theory" proposed by Prof. Agassiz seems well fitted to account for the natural polishing of rocks. It does not appear essential to that theory, that there should be mountains or hills, but only a belt of ice of sufficient depth and magnitude, and a suitable climate, to produce such results, as are now found to be taking place under the glaciers of the Alps. As the masses of ice do not move or descend by gravitation, no deep or steep valleys are necessary. We need only *the mass of ice.* Such glaciers formed in a level, or nearly level country, would have no moraines on the sides or middle, but only in front, or would have only *terminal* moraines, from the carrying forward of the sand, gravel, and loose blocks on the surface of the rocks. There might, indeed, be a small accumulation of earthy materials on the side, from the tendency to slide sideways from the front; but this effect must be relatively small. We cannot, therefore, make application of this theory with *much safety* to the waved form of portions of the earth, or those sudden elevations and depressions which are so common in our country. To refer to no others than those presented in Prof. Hitchcock's Geology of Massachusetts, ought not other evidence than the mere existence of the form of the surface to be required? According to Agassiz, an examination of the moraines in the Alps would prove their composition such as the theory supposes, rough and angular blocks of the rocks mixed in confusion with the finer materials. Similar proof should be obtained before it can be reasonably maintained, that such appearances are in truth *moraines*. The dashing of mighty waters, with their reaction, might leave the sand and gravel in the peculiar form which these supposed moraines present, and the whole result be that of diluvial action. In this section of the country are such appearances on a great scale; but in many instances, the composition of them, the sand and gravel, finer and coarser, and in regular layers, has been so far exhibited at their base, and on their sides, or towards their top, that there can be no doubt about them. It is lamentable that Geology has so often carried the application of favorite hypotheses to a ruinous extent.

To the polishing of the surface there is not the same difficulty in the application of the theory; for Agassiz shows, that the polishing actually takes place under the glacier, and this effect, the polished surface, actually exists under our feet. The rock chiefly polished here is the limestone above the calciferous slate of Eaton, hard, slightly granular, pretty compact, and bituminous. In a few places, the geodiferous lime-rock on this, is the polished stone, but is here only a thin layer, while the other is a thick stratum. The polished surface is found in many places in the city on both sides of the Genesee, so that many acres are polished sometimes forty rods in length; just west of the city are a hundred rods uncovered, and in other places ten rods, four rods or a few feet only in length, but in different directions, making it highly probable that a large surface is polished. In several places the polish stops, for no reason that can be assigned. On the east side of the river, the polished surface has not been found over one fourth of a mile distant, till yesterday I discovered it about a mile east of it. The polish is not on the same level, but passes over the outcropping edges of the strata, rising several inches in a foot or two, and showing the strata worn at the edge very thin; yet the polish is as perfect as on the level, and the rock shows no signs of its stratification till it is broken up. It is sometimes *curved* too in a few inches, as if the surface had been worn into a shallow hollow by the polishing surface. From the Genesee Valley Canal, where the rock is polished, the surface rises to the west, perhaps twenty feet in one hundred rods, and the polished surface has been found every few rods by the digging of wells or cellars.

The polished surface has sometimes only a thin covering of earth upon it, and is sometimes under earth, ten, twenty, and thirty feet or more deep, just as it has been heaped upon it by diluvial agency. This erratic group is sand, clay, gravel, and bowlders of the primitive rocks, which must have come a great distance, and of sandstone, which has been moved only a few miles, and of geodiferous limestone, which is still less removed from its proper place. The former set of bowlders seems to be buried at a greater depth than the others. The striæ and furrows show that large and sharp bodies must have been moved on the surface. May not the polish have been first wrought by earth and sand, and the furrows effected by that diluvial action which brought on the erratic group far from the north?

Notes explanatory of a Section from Cleveland, Ohio, to the Mississippi River, in a southwest Direction; with Remarks upon the Identity of the Western Formations with those of New York. By James Hall.

In the American Journal of Science and Arts for January 1842, I gave a hasty sketch of some observations made during an excursion through the Western States, as far as the Mississippi river. This tour was undertaken, as I then stated, with a view to trace the groups of rocks known in New York, westward, and if possible to identify them with those to which different names had been given by the Western Geologists. No extended attempt of this kind had been made from actual examination and comparison, so far as I know, and the inferences from published reports, and the occurrence of certain fossils, had not proved satisfactory. The formations of the West, as described, did not correspond with the order as established in New York; and the discrepancy could only be accounted for by supposing the thinning out of some important formations, or the occurrence of others not there existing.

Mr. Vanuxem, whose observations were published in Silliman's Journal in 1829, was the first person who pointed out the similarity of some of the Western formations with those of New York. He identified the lower rocks of Ohio, Kentucky, and Tennessee, with the Trenton limestone, from the occurrence of many of the same genera and species of fossils common to both. Before starting on this tour, I was referred by him to some localities which were important in settling the questions of identity or difference, and I am indebted to the same source for information of the existence of the Birdseye and Trenton limestones at Frankfort in Kentucky.

Having, in New York, adopted certain subdivisions or groups of the strata, which are strictly in the order of nature, it became a matter of much interest, to ascertain how far the same subdivisions would hold good in distant localities, where there was evidently great change in lithological characters. In employing geographical names for groups or individual rocks, it is desirable to know the locality of greatest developement for the whole country, and when this is ascertained, the name should be adopted. But until the extent and comparative developement of each rock is known, perfect local names cannot be prefixed; and as a step toward the perfection of this nomenclature, the place of greatest developement in the district under consideration should give the name.

This examination westward also afforded a good opportunity of testing the value of fossil characters, when applied to the same strata extending over wide tracts of country, and the results will be seen, as we proceed, to have been mostly satisfactory. The value of lithological characters at the same time was found to fail in a great degree, and though in some cases persistent, yet alone they would be found insufficient and often lead to erroneous conclusions. From the investigations made in New York, we had learned that groups, which at one extremity of the State are of great importance and well characterized by fossils, cannot be identified at the other extremity; and the same is more emphatically true of single rocks.

The Niagara group, so well defined by the topographical features of the country, as well as by both its fossil and lithological characters, no one has yet attempted to identify to the east of Little Falls. Almost the same may be said of the Onondaga salt group and the Medina sandstone; while on going in the opposite direction, we find several important members of the Helderberg series entirely wanting west of Cayuga Lake, and the Oriskany sandstone existing only in patches here and there.

The undisturbed range of these deposits, with the great extent of unbroken outcrop bordering the Ontario valley and its continuation along the Mohawk, has enabled us to acquire a very perfect knowledge of the changes in the character of strata in their east and west extension. While such changes have taken place in important groups, others of less apparent importance and of much less thickness, are found remarkably persistent.

In making my examinations westward, the groups and individual rocks of New York, as adopted in the annual reports, were made the basis of reference.

The Lake Erie shore, from the New York and Pennsylvania line (a point to which previous investigations had extended) to Cleveland, presents nothing of peculiar interest, being occupied by the rocks of the Portage group, which for the most part are destitute of fossils, except the remains of marine vegetables and a few Goniatites. The accompanying section (Pl. XII) extends from Cleveland to the Mississippi river, there being no rock represented which was not actually seen. Though westward, from Leavenworth, Indiana, it passes a little north of the line examined, in order to present the great limestone formation on the Mississippi, as a more prominent feature, than further south, it being low and obscure near the mouth of the Ohio.*

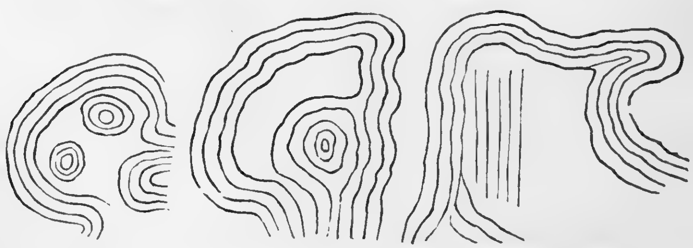
The rocks seen near Cleveland, Ohio, are perfectly identical with those of the middle portion of the Portage group, or Gardeau flag-stones, being a continuation of the same as traced from New York along the lake shore. In following the road to Cuyahoga Falls, the Portage sandstone, or upper part of the group, is seen at Newburgh, and is there underlaid by green shale. These are equivalent to the Waverley sandstone of the Ohio Reports, as was afterwards ascertained by visiting the quarries at Waverley. From Newburgh we pass over the shales and sandstones of the Chemung group, till we arrive upon the conglomerate which is well developed at Stow and Cuyahoga Falls.

This conglomerate which, so far as I could discover, is identical with the outliers of a similar mass in the southern part of New York, is the fundamental rock of the great coal formation throughout the greater part of the western country, appearing everywhere either as a coarse sandstone or a pebbly mass, and affording an unerring guide to the proximity of coal. Some portions of the mass at Cuyahoga Falls are destitute of pebbles, and furnish a fine reddish or brownish sandstone used for building. The greater part however is composed of coarse materials, with white quartz pebbles. This character is exhibited in great perfection along

* I am under obligations to Dr. Owen for much valuable information of the northwestern region beyond the limits of my researches, and I had hoped to be able to present a section which he liberally furnished me, extending across the formations from Prairie du Chien to Tennessee, and crossing the Rock River near Dixon's Ferry, and the Ohio near Rockport. This section exhibits the northwestern margin of the great Illinois coal formation as resting upon the Cliff limestone.

the road from Stow to Cuyahoga Falls, and in the vicinity of the former village. Just below the falls its junction with the shales and sandstones of the next group is well exhibited. In the lower part of the conglomerate at this place, my friend, Mr. Newberry, has obtained a large number of fossil plants, with the fruit of several species. They are imbedded in a friable brown sandstone, highly stained by iron, and though mostly casts, are in a state of good preservation. I afterwards obtained some similar fossils from conglomerate near Deer creek, below Leavenworth, Ia.

Although usually destitute of fossils, this conglomerate possesses some characteristic marks which may serve to distinguish it at very distant points. Among these, in New York, are thin seams, often apparently concentric, of hydrated peroxide of iron, crossing the mass at various angles, or curved and contorted. Sometimes these appear as small nodules which desquamate on exposure, or when struck with the hammer. In such cases the outer portions only are composed of the hydrated per-oxide, while the inner part is still a carbonate of iron, the change having probably been effected by the percolation of water. At Cuyahoga Falls, I saw some beautiful exhibitions of these iron seams, which the annexed diagram will serve to illustrate. The black lines,



1. 2. 3.

represent the iron ore, and the lighter parts the sand. These appeared in the perpendicular face of the cliff, where the stream had excavated its channel. The central mass in most cases is sand, and each concentric lamina of ore is separated from the other by a band of the same, apparently exhibiting a tendency to become nodules, but the particles being resisted by the greater weight of sand, were prevented from forming a common mass. This illustrates very plainly the process by which spheroidal masses are sometimes formed in rocks of a different composition; the material of like nature, whether from attractive force, crystallization or otherwise, commences to aggregate the mass. A small nucleus is formed, and if there be no impediment it goes on increasing by concentric coats, and by attracting the material of the same kind to itself from all directions. If the resisting medium do not too powerfully oppose the accretion of the particles, they unite in a solid sphere: if the resisting medium overcomes the power of attraction, concentric rings are formed, as in the diagram, Fig. 2. Sometimes two centres are formed near each other, as in Fig. 1; and in this case one side may increase faster than the other, the matter between them being divided, or the two may finally unite in one, producing the fantastic shapes often seen in *Septaria* and other accretionary forms. The nucleus is not always spherical, and then neither will be the final production. Fig. 3 exhibits concentric laminæ with slightly undulating ones in the centre, and shows a tendency to form another centre on the upper right hand margin. The graphic effect of these appearances cannot be conceived from the sketch given. In the face of the cliff, numerous sections of concentric spheres were seen, and nearly all exhibited in a greater or less degree the phenomena here desoribed.

This character, so well illustrated at this place, continues in every locality, in greater or less degree, as far as examined westward; the ore frequently forming nodules or accretions. From what I was able to learn from other observers in Michigan, there is a considerable quantity of similar ore in the same situation in that State.

In the vicinity of Cuyahoga Falls, the conglomerate may be seen passing beneath the coal which is worked in several places in that neighborhood; the principal mines which I saw being those on the farm of Henry Newberry, Esq. Below the falls the Chemung group is distinctly characterized, containing however few fossils compared with the same further east. I obtained enough to convince me of the identity, and I have since received from Mr. John Newberry several others, which at that time I did not see. The most abundant fossil is a species of *Strophomena*. Beside this, there is an *Atrypa*, a *Cypricardia*, an *Orbicula*, a *Lingula*, a small *crinoid*, and one or two undescribed forms.

A section at this place gave the following rocks, in a descending order.

75 ft. { 1. Coarse grained, friable, porous sandstone, sometimes reddish
2. Finer grained sandstone, passing gradually into that above and below.
3. Shaly sandstone with shale below. }
4. 2 to 6 feet, coal of fine quality.
5. 6 feet, fine grained sandstone.
6. 100 feet, conglomerate and sandstone.
7. 100 feet, shales and sandstones of Chemung group.
8. Fine grained sandstone of Portage group.

At Akron, the rocks of the Chemung group appear beneath the conglomerate, which is there in its lower part a coarse gray sandstone. The same fossils as before noticed, occur on a small stream by the side of the canal, below this village.

Passing south from Akron, I came to beds of coal, succeeded by a dark colored shaly limestone, which abounds in fossils. Among these were two or three species of *Delthyris*, several of *Atrypa*, a *Productus*, and crinoidal joints in great numbers. A limestone holding this position among the coal beds is a very interesting circumstance, when taken in consideration with the absence of any limestone representing the Carboniferous of Europe. One species of the *Delthyris*, also, is very similar, if not identical with Sowerby's figure of *Spirifera attenuata*, and the other fossils have all the aspect of those figured by Sowerby and Phillips from the carboniferous limestone of England. A similar rock appears in the southern part of the State, where I obtained some of the same fossils as at Greentown. It also appears in several places in the vicinity of Canton.

Passing to the south and west along the road to Columbus, we soon leave the coal formation and come upon the groups below. These present few important features, except a gradual thinning in that direction, and the almost entire absence of fossils. The Chemung becomes scarcely distinguishable from the Portage group, and both are known in the Ohio Reports as the Waverley sandstone series. From beneath these, pass out all that remains of the Hamilton group and Marcellus shales, the whole known as the black bituminous shales of the Ohio Reports, and possessing, as a whole, the character of the Marcellus shale of

New York. I was not so fortunate as to meet with fossils in any part of this mass examined, though they do occur in some places. This rock was traced nearly to Columbus, and a short distance to the west of that place the Corniferous limestone of New York appears, presenting its characteristic fossils. This mass is the upper part of the cliff limesone formation of Dr. Locke, the name by which it is generally known in Ohio.* The localities where I saw this rock exhibited less hornstone than is usual in New York, but the position and fossil characters were unequivocal.

After ascertaining the existence of the Corniferous limestone, and the middle and lower members of the cliff limestone, for some distance west of Columbus, an offset was made into the coal region of the southern counties, and the line of observation again taken up on the Ohio river at Portsmouth.

In following down the river, the limestones appear rising from beneath the shales, as represented in the section. Numerous localities are presented in the river bank and ravines, where the blue limestone exists in great force; the most interesting, before reaching Cincinnati, are in Adams county, Ohio, and Maysville, Kentucky. An examination of the fossils at Maysville, convinced me of the identity of the Blue limestone of Ohio, and the Hudson river group, of New York. The evidences of this identity are the following: the mass consists of green shale, or marl, alternating with courses of bluish crystalline limestone, of a peculiar aspect, resembling that associated with the Clinton group, of New York, particularly the portion containing *Pentamerus oblongus*. Thin layers of gray sandstone occur, sometimes separate, and at others attached to the limestone in wedge-form masses, and always containing a species of fucoid, which I had learned to consider a characteristic fossil in New York.

Further examinations brought to light the *Pterinea carinata*, two or more species of *Cypricardia*, a *Strophomena*, *Cyrtolites ornatus*, and the *Bellerophon bilobatus*, as well as the abundant

* See Report on the Geology of the southwestern counties of Ohio, by Dr. Locke. — *Ohio Geological Reports*. 1838.

little shell, (*Orthis testudinaria?*) *Orthis striatula.* The latter fossil ranges through the Hudson river group in New York, as it does through the Caradoc sandstone of England. This association of fossils, with the peculiar aspect of the limestone, and the presence of sandstone with fucoides, seemed indubitable proof of the position of this mass. Neither the character of the rocks, nor of the fossils, indicates the Trenton limestone to which heretofore it has been referred. Numerous other fossils, unknown in New York, are found at Maysville, the most abundant being several species of *Orthis* and *Delthyris.*

The cliffs of Cincinnati were next examined, and the same evidence, in a higher degree, brought forth. At this place I had the gratification to meet Dr. Locke, who gave me every information relative to the limits of the two formations, Cliff and Blue limestones, as known in Ohio, and I afterwards derived great assistance from his Report on the Geology of this part of the State. I was also fortunate in meeting, at this place, with several gentlemen who were zealously engaged in exploring the rocks of the vicinity, and who voluntarily aided me in my objects. From Mr. J. G. Anthony, Mr. Clarke, Mr. Carley, and Mr. Buchanan, I received many characteristic fossils of the locality.

The section made there at this time presented the following features.

On the Kentucky side of the river, at the water level, (May 8th, 1841,) the rock seen was a green shale with thin laminæ of crinoidal limestone, containing few fossils. Among these the *Triarthrus Beckii* is the most prominent, and with fragments of *Isotelus*, and a few imperfect shells, were all that I obtained. In New York, the *Triarthrus* is never found below the Utica slate, and is a characteristic fossil of that mass; though it does occur somewhat rarely in the lower part of the Hudson river group. Taken in connection with other circumstances, and the character of the fossils in the succeeding rocks, it seems a fair inference that this is the equivalent of the Utica slate, or at least not far above it.

At low water, on the Ohio, a lower rock appears, and though the specimens I have seen contain no unequivocally characteristic fossils of the Trenton limestone, yet it may exist here, and Mr. Vanuxem informs me that he saw it in the valley of the Little Miami, a locality which I did not visit.*

Proceeding upward from the green shale with *Triarthrus*, we find a somewhat similar shale, with thin layers of sandstone, characterized by the presence of *Trinucleus* and *Graptolites.* Still above this we find alternations of shale, or marl, and limestone, with *Orthis striatula* in great abundance; with this shell and above it occur *Strophomena sericea, S. alternata? Pterinea carinata, Cypricardia augustifrons, C. modiolaris, Cyrtolites ornatus*, with a great abundance of corals and other fossils. Among these are *Bellerophon bilobatus, Orthoceras*, and two or more species of *Orthis* similar to, or identical with, those of the Caradoc sandstone of England. Fragments of *Isotelus* are abundant, also a species of *Calymene.*

From the enumeration of some of the forms, it will be perceived that we have here an assemblage of fossils similar to that of the Hudson river group of New York. For here, as in Ohio, the shales, with *Triarthrus*, are succeeded by green shales and slaty sandstones containing *Trinucleus* and *Graptolites*, with other fossils. The *Orthis striatula, O. callactis, Strophomena nasuta, Pterinea* and *Cypricardia*, are likewise characteristics of this group, as well as *Bellerophon bilobatus* and the same species of *Orthoceras. Strophomena sericea* occurs in Ohio, completely covering the surface of thin layers of limestone, as in New York. In both places are seen thin courses, composed almost wholly of the stems of *Crinoidea*, and the species appear to be identical.

The remains of *Isotelus*, several species of which occur, have always been considered sufficient proof of the identity of this rock with the Trenton limestone of New York, and these fossils

* Very careful and extensive examination is often necessary, in order to identify rocks by the presence of characteristic fossils. In the rocks of Cincinnati, Maysville, and other places, occur fossils of the Trenton limestone. Among them are *Orthis striatula, Strophomena* (*Leptæna*) *sericea, S. alternata? Bellerophon bilobatus, Favosites lycoperdon*, and others. The last named fossil occurs with *Bellerophon bilobatus* and *Orthis striatula* in the Caradoc sandstone of England. The *Calymene* of these rocks at the West, usually considered identical with the Trenton species, is probably distinct.

have been chiefly relied upon. All the specimens which I saw, however, are of different species from those of Trenton. So that although certain species of this genus do occur in the Trenton limestone, and are characteristic of that formation, others are not necessarily so, and unless we take wide ranges in our groupings, we cannot depend on generic types. In this case the amount of evidence appears to be about equally divided between the Trenton and Hudson river groups; but since there are fossils decidedly typical of the latter, and we know that in New York they never occur in a lower position, we are compelled to admit that this formation is of the same geological age.

Besides the fossils enumerated, are many which do not occur in New York; among these a beautiful crinoid and several species of *Delthyris*, *Atrypa* and *Orthis*. It should not be omitted, that in the hill-side at Cincinnati, we find, attached to the limestone beds, numerous thin wedge-form layers of sandstone, which usually contain a species of fucoid similar to one in the Hudson river group, and the same as that noticed at Maysville. Besides the fucoid, this sandstone contains a species of *Strophomena* similar to one of the same group in New York.

From the evidence here adduced, it appears that in the West there is not so great a transition from the Black river and Trenton rocks to those above, as in New York; and that, from the fact of the greater similarity of lithological character, and the occurrence of many important fossils, specifically and generically similar, throughout the mass, we may yet be inclined to consider the whole as one great natural group, exhibiting well defined lines of minor subdivisions. The termination of the Hudson river group, in New York, is the first point of marked and unequivocal change in the fossil characters. Below this point there are many forms which pass from one rock to another upward, often rendering it almost impossible to decide what are to be considered as characteristic. In every case, however, certain species are entirely limited to the mass they occupy. The great range of some of these species through the lower rocks, with their total extinction at the termination, indicate a great change in the condition of the ocean. Such a change is further corroborated by the occurrence of a thick and extensive mass of conglomerate, which succeeds the Hudson river rocks in New York. These suggestions are offered, not with any view to merge in one formation what can be considered as decidedly distinct, but with the desire to offer some facts toward the foundation of general groups or classes, to which all the numerous minor subdivisions may be referred.

The junction of this group with the cliff limestone cannot be seen in the neighborhood of Cincinnati; but in passing down the river, the two appear in juxtaposition before reaching Madison, Indiana. In the Ohio Reports, Dr. Locke refers to this place as exhibiting, in a very perfect manner, the contact of the two rocks, cliff and blue limestones, which are well seen in the deep cutting for the rail-road one mile southwest of the village, and in a ravine still further below.

The fossils of the blue limestone at this place illustrate the same view as at Maysville and Cincinnati. The *Pterinea carinata*, with one or two species of *Cypricardia*, are common, while *Strophomena*, *Orthis*, and others, abound in the middle portions, together with the *Atrypa capax* of Conrad, a species not seen at Cincinnati. Large numbers of *Cyathophylli* occur, of a species different from any in the higher rocks. Near the junction of the blue and cliff, which latter is strongly contrasted in color, as well as other characters, there occurs a stratum of twenty-five feet thickness, of a greenish gray sandy shale, containing *Cypricardia modiolaris*, and numerous spherical masses of coral, (*Porites*,) which lie in two courses, or ranges, near the top of the mass, and separated by a few feet of shale from each other. Some of these masses attain a large size, being three or four feet in diameter, while others are but a few inches.

The lower member of the cliff limestone at this place is a calcareo-siliceous mass, with green stripes and spots, and crumbling on exposure to the air. It appears quite destitute of fossils, so far as I could discover. About fifty or sixty feet above the base of this mass, I noticed a strong ferruginous exudation; but the point being at the junction of the rock with the loose materials above, I was unable to discover any ore in place. It is possible that this mass may represent the Clinton group, as Dr. Locke showed me specimens from the same, in the eastern part of Ohio, which, as I understood from him, forms the lower part of the cliff limestone. This rock, which plainly succeeds the shales and limestones equivalent to the Hudson river group, is marked by patches and laminæ of green shaly matter, strongly resembling some portions of the intermediate mass between the Medina sandstone and the Clinton group, being an intermixture of the green shale of the one, and the sandy matter of the other.

Time, however, did not admit of going into detailed examinations, regarding the individual rocks, or groups, composing the cliff limestone, the object being a general identification of larger subdivisions. From examinations made at a short distance from this place, I learned that the friable sandy mass just noticed was succeeded by a harsh, porous limestone, apparently magnesian in composition, and possessing the general characters of the Niagara limestone in New York. At this place I was unable to find any fossils save a few crinoidal columns, which gave to the rock much the appearance of the lower part of that at Niagara Falls and Lockport. The examinations of this rock in other places, where I found fossils, and was able to trace the succession upwards, left no doubt of its identity with the Niagara mass.

It should be remarked, that soon after leaving Cincinnati, the rocks are seen to dip to the west or southwest; and at Madison the base of the cliff limestone has approached within one hundred and fifty or two hundred feet of the river. From this point it continues to dip in the same direction, gradually approaching to the river level, and finally entirely disappearing beneath it at Louisville or the falls of the Ohio. The river, at the time, being high, did not permit an examination of the rock directly at the falls, but the excavation of the canal below Louisville has developed, in the loose fragments, the character of the rock, which consists, apparently, of the water lime, and perhaps some portion of the Onondaga salt group, with the limestones above. The most satisfactory exhibition, however, was a few miles further up the river, where the rocks are very well exposed. Along the line of rail-road, and in the banks of a small stream about three miles from Louisville, the same rocks are seen. The highest mass at this place, contains a species of *Calymene* characteristic of the Corniferous limestone of New York, as well as several shells equally so, among these a peculiar variety of the so called *Atrypa prisca*, and a species of *Strophomena;* both shells are confined to this mass. Below this was seen a mass with *Favosites* and *Cyathophylli*, which could be identified with no other rock than the Onondaga limestone, possessing all the essential features of that rock, both as regards lithological and palæontological characters. Passing from this over strata resembling the lighter colored portions of the water-lime series of New York, we came upon a drab-colored mass, in thin layers, abounding in *Catenipora* and *Favosites*, and below this a lighter or ash-colored limestone, in thick courses, destitute of fossils. Such, simply, was the order in which the rocks were examined at this place, and from which collections were made.

From the examinations made here, at Madison and other points, the unavoidable conclusion is, that in the cliff limestone we have the Helderberg series of New York; or at least the two persistent members, Onondaga and Corniferous, with the water lime and perhaps a meagre representation of the Salt group, together with the Niagara limestone. And if the inference regarding the Clinton group at Madison be correct, and which seems probable from the fact that Dr. Locke has detected this group embraced within the cliff formation in Clinton and Adams counties, Ohio, we then have conclusive evidence that this formation, as defined, embraces all the rocks and groups from the Helderberg division or Corniferous limestone, to the Clinton group inclusive; and perhaps also, the representations of the Medina and Gray sandstones, if any such exist. Nothing was seen, however, to indicate these in their proper forms, and the inference was that they had disappeared before reaching Cincinnati. Still, however, more minute examinations may prove the existence of some diminutive representative of these masses, though in other forms than they appear in New York.

After making these investigations in the vicinity of Louisville, I had the gratification of seeing, in the cabinet of Dr. Clapp, at

New Albany, many of the fossils common to the rocks of New York, and which fully confirmed my views relative to the position of those examined. These fossils were principally from the rock at the falls of the Ohio. From comparing my observations of other rocks with those made by Dr. C., I became still further convinced of the identity of different portions of the formations of the West with those of New York,* and that the limits of many of the rocks were as well marked there as at the East.

Above the limestones last described we meet with a "black bituminous shale," which, from position, seems to be the equivalent of the Marcellus shale of New York,† and is the only representation of that rock, the Hamilton group and Genesee slate; for we pass directly from this to the green shales and slaty sandstones of the Portage group or Waverley sandstone series of Ohio. In the examinations made in these rocks for several hundred feet upwards, no change from the Portage to Chemung groups could be identified, fossils for the most part being absent. I should not omit to state, however, that in passing beyond these greenish slaty rocks to a more micaceous and ferruginous yet friable sandstone, I found several shells which bear close analogy, if not absolute identity, with the Chemung species. But finding afterwards, in other parts of this sandstone, shells evidently belonging to carboniferous types, I was led to question the inference as to absolute identity.‡ Further investigations proved that this sandstone, in passing upwards, became interstratified with beds of limestone, and thin courses of öolitic limestone with fossils occured in several places. These latter were not persistent, but in some places were found several inches thick and soon dis-

* From a letter of Dr. Clapp to the Philadelphia Academy of Natural Sciences, dated February, 1842, I am happy to see that his views regarding the identity of the rocks of that region with certain formations of New York essentially correspond with what I had expressed in the Am. Journal of Science of January preceding.

† Near New Albany this shale is one hundred and four feet thick, "in other situations it is only fifty feet thick," — *Second Ann. Rep. of Geological Survey of Indiana*, page 15.

‡ The fossils referred to as similar to those of Chemung, are a species of Delthyris, a Strophomena, an Atrypa and an Inoceramus. Their absolute identity has not been determined from want of an opportunity to compare with specimens from the rocks of New York.

appeared entirely, or left only a line of calcareous matter, marked by the presence of Producti. Still higher in this rock are some quarries, where a mass of limestone eleven feet thick is wrought for building stone. The lower part of this mass is a compact öolite, while the upper is rather coarsely crystalline with fragments of fossils. Below this, and separated by a course of sandstone of several feet in thickness, is another thick bed of limestone, and the whole is succeeded above by sandstone like that below. The height of these quarries above the black shale is four hundred and fifty-four feet; and the thickness of shales and sandstones between this point and the main limestone above, is fifty or sixty feet more.*

These rocks are marked in the section by the name of sub-carboniferous, and although the fossils, and the character of the intercalated beds of limestone, indicate the commencement of the same era as the carboniferous limestone, yet it requires that a limit should be fixed between what is to be strictly referred to the Carboniferous period, and older deposites. The gray sandstone here spoken of contained in numerous localities a large species of Productus, resembling P. hemispherica, a carboniferous fossil, while there seemed to be a gradual transition from rocks of the Chemung group to those above, indicating no cessation of deposition, and scarcely a change in lithological character, except the occurrence of thin beds of limestone.†

Pursuing my investigations down the Ohio from this place, I found the group which is designated sub-carboniferous, succeeded by a thick and persistent mass of limestone, presenting

* The thickness given was furnished me from the surveys of road engineers, in a Letter from Dr. Clapp, of Sept. 2nd, 1842.

† I find, on reference to the Report of Dr. OWEN on the Geology of Indiana, that he has denominated the rocks here described, as well as the succeeding limestone, "Subcarboniferous." This fact was overlooked till the section was in the hands of the engraver and the paper entirely written. The limestone following is denominated in its different parts by Dr. Owen and Dr. TROOST, as öolitic, Pentremital, and Archimedes limestone. After taking all possible means to obtain a copy of Dr. Owen's Report upon the Lead region, I have been unsuccessful, and this must be my apology for appearing ignorant of what has been done in that region, except of the general fact of the identification of the Lead-bearing rock with the Cliff limestone of Ohio and Indiana.

features unlike any of the limestones seen in New York or Ohio. By reference to the section, this limestone will be seen extending eastward to the vicinity of New Albany, Ia., and passing beneath the level of the river, near Leavenworth, about fifty miles below. It is visible, forming a cliff along the river, for nearly the whole of this distance, where it passes under the conglomerate, or its representative, a coarse gray sandstone, showing diagonal lines of deposition, with seams and nodules of hydrate of iron. This limestone reappears upon the river in several places between Leavenworth and the Wabash, at some of which examinations were made. Beyond the Wabash it reappears and continues to the Mississippi river, forming a low cliff often for many miles in succession. On the Mississippi, above the junction of the Ohio, it soon appears, forming at first but slight elevations, but soon rising into cliffs of from one hundred to two hundred feet in height. It presents this character of cliffs nearly to St. Louis, beyond which place it does not rise so high, but continues in view as far as the Rock river, and extends up this stream beyond Dixon's Ferry. From this rapid sketch it will be seen, on reference to the map, that this limestone occupies an extensive area east of the Mississippi river, and stretching westward its limits are unknown. On the south of the Ohio it is known to extend into Tennessee, and from the Reports of Prof. Rogers, it is a very extensive and important rock in Virginia. It thus becomes equally important with any of the great limestone formations heretofore described in this country, in regard to position and extent. When it shall become more generally known, it will be found a prominent horizon for the proximity of the coal strata, as, in its absence, is the conglomerate further east.

The examination of this limestone at Leavenworth, gave the following characters:— The lower part of the rock is compact and fine-grained, breaking with a smooth conchoidal fracture. This portion has been used for lithographic stones, and for small pieces serves the purpose very well. Above this portion the character is somewhat irregular, with light-colored chert or hornstone, which is often translucent. I was unable to find any fossils thus far upward, in the mass at this place. Above the cherty layers the rock becomes coarser grained or semi-crystalline, and contains numerous fossils of the genera *Delthyris*, *Atrypa*, and large numbers of the *Pentremites*. The most remarkable fossil of this portion of the rock, and which occurs just above the fossils named, is the *Archimedes* of Lesueur, a singular coral, appearing as an expansion somewhat like the *Retepora* twisted spirally round an axis; or rather, the edge of the coral, by thickening and folding, forms the axis. This curious fossil always holds the same position in the rock, the character of which differs from that above or below, being often ferruginous or yellowish in color and fine-grained. This portion of the rock contains, besides the Archimedes, one or two other corals, and one or more species of *crinoidea*.

This portion is succeeded by a beautiful light-colored öolitic mass, containing numerous fragments of fossils, the principal of which were Producti, some perfect specimens being obtained. A *Trilobite*, a portion of the head of which resembles an *Asaphus*, also occurs in this part of the rock. It is a very persistent mass, being seen at numerous and distant points. Its character as an Öolite, is as perfect as specimens from Bath, in England, and its chalky and fissile nature, considered alone, would almost induce one to regard it as a more recent formation. Its position, however, cannot be mistaken, for, about one mile below Leavenworth, it is seen passing beneath the gray sandstone before mentioned. At this point, without any intermixture of the two deposits, we pass from a pure öolitic limestone to an equally well-characterized quartzose sandstone.

This limestone was again examined near the mouth of Oil Creek, Ia., where it presented the same essential characters as described, and the same order of the parts. Opposite the mouth of Little Blue river, on the Kentucky side, the junction of the limestone and conglomerate presents a singular siliceous aggregate, containing abundance of shells, and having somewhat the character of Buhrstone. From this place to the Wabash, there was little of interest to be seen; the rocks approaching the shore in many places, indicated along the whole distance the existence of the great coal formation of the Illinois or Wabash basin. From the section it will be perceived that the Wabash flows in the depression produced by a synclinal axis, and from thence the strata gradually rise to the westward.

The limestone soon rises from beneath the river-level, and continues in view nearly to the Mississippi, being obscured only by superficial accumulations. After ascending the Mississippi for some distance, the rock again appears. The great valley, or "American bottom," is bounded on either side by abrupt cliffs of this limestone; the river meandering in its course from side to side, sometimes runs at the base of the perpendicular rock, while the opposite side presents a broad level bottom land, covered for the most part with luxuriant forests of primeval growth. These cliffs form some of the most picturesque scenery, and, with the small shot towers upon the overhanging margin above, suggest the idea of stupendous castle walls of Cyclopean architecture, crowned with the sentinels' towers.

Between the point of its first appearance on the Mississippi and its final disappearance near the mouth of Rock river, I examined it at numerous points, and always found a very uniform lithological character, which alone is sufficient to distinguish it from all other rocks, and enable one to identify it with its commencement in Indiana. The fossils, however, are constant and unerring guides, which left no room for doubt. The rock, on fresh fracture, has a peculiar light gray color, much of it crystalline, while other portions are compact and fine-grained, presenting the appearances described at Leavenworth.

At St. Louis I obtained several fossils, principally corals and crinoidea, all of which, so far as I know, differ from those found in any lower rock. Dr. B. B. Brown, of St. Louis, politely presented me with specimens of Productus, from his cabinet, which were found in that vicinity, and which correspond with the British *P. Martini*. Having since had an opportunity of examining a small collection of fossils from the carboniferous limestone of England, in the Lowell Institute, I found many of the same species as those of this great formation, leaving no doubt of the identity of the two. The difficulties, therefore, in the way of comparing our rocks with those of Europe, seem in a fair way to be cleared up, and we learn that among all our limestone formations, in the eastern part of the United States, the true carboniferous limestone is wanting, its fossils appearing only in a few places in shale and sandstones associated with the coal strata.

For the greater part of the distance along which this limestone was seen, it is but slightly inclined, often appearing horizontal. The only deviation of importance noticed, is near Herculaneum, on the Mississippi river. At this place there appears to have been an extensive uplift in a northeast and southwest direction, elevating the strata at an angle of thirty degrees; and from the existence of one or two small islands, seeming, at some remote period, to have obstructed the course of the river. From the shallow water at this place, the uplift appears to have been of more recent origin than the excavation of the river channel, otherwise there appears no reason why the depth here should not be as great as in other places.

Along the Mississippi river the common fossils were a large species of Delthyris, with a smooth Orthis or Atrypa, in form like the A. *concentrica* of the lower rocks, but larger; these appeared at numerous localities which I had opportunities of examining. Several species of Producti, with the larger valve very much arched, and the upper one concave and slightly wrinkled, are constant, and good guides for this mass. My friend Dr. Owen has recently figured some of the common forms in the July number of the American Journal of Science. Residing upon this formation, his opportunities of investigation are ample, and we may expect that his zeal will lead to the full developement of its interesting organic contents.

After leaving the carboniferous limestone, near the mouth of Rock river, the coal and associated rocks appear, and beyond this point the lower limestones; the intermediate rocks not being seen. There is evidently either an abrupt synclinal axis, or fault, which has brought up the lower masses. From want of sufficient time to investigate this point, I was unable to determine the precise cause, or amount of change. The contrast between the two limestones thus brought into proximity is very striking; the gray or ashen color is exchanged for a brown or iron-stained rock, harsh to the touch, and composed of small crystalline grains. The mass rises in broken or detached knobs or pinnacles, presenting a ragged and irregular outline, in place of the uniform cliff, formed by the higher limestone. In tracing this limestone up the river as far as Galena, its lithological character is the same as that of the middle and upper portions of the Niagara limestone, and all its associations are the same. The cliffs in many places, particularly on the river above Dubuque, have all the appearance of those at the falls of Niagara, so far as regards lithological character, weathering, &c. Above the town of Dubuque, this rock (cliff limestone) rests upon the blue limestone, which, according to Dr. Owen's statement, is much thinner here than in Ohio; but not having traced it to its termination below, I am unable to speak from personal observation. Specimens which I saw from the lower part of this rock about Prairie du Chien, indicate the presence of the Trenton and Black river limestones, by the large Orthocerata and other fossils. From a section made by Dr. Owen, it appears that there are beds of sandstone, interstratified with, and underlying the blue limestone.

It is in the cliff formation as before described, that the lead ores of Illinois, Wisconsin, and Iowa are found, a part only of the rock yielding these ores. This portion appears to correspond to the Niagara limestone; the upper part of the "cliff rocks," which represents the Helderberg series, being destitute of metallic veins. Although the rock contains few fossils, these indicate its position to be the same. The Catenipora, which in New York occurs far more abundantly in the Niagara limestone than in any other rock,* is found here in great abundance, with Aulopora and a few other fossils. The next fossiliferous group below the lead-bearing rock on the Mississippi river, is that corresponding to the Hudson river group. If the Clinton group exists, it has there become so incorporated with the rocks above, as to be overlooked as a distinct formation. This point requires examination, and it is possible that some representative of the group may be found there. Being a very variable assemblage in New York, it would not be surprising to find it under another aspect or even incorporated with the Niagara group as far west as the Mississippi. Its last appearance in New York on the Niagara river, is in the form of a mass

* See Note.

of limestone twenty-five feet thick, with about four feet of shale below; the limestone at this point has lost the sandy and impure character which it has further east, and assimilates more with the lower part of the Niagara limestone. The only fossil met with in this mass on the Niagara river, was the *Delthyris radiatus*, which is found extending through the shale above, and in the lower part of the limestone.

In crossing the country from Galena to Chicago, few opportunities offered of examining the strata except at detached points. The only rocks seen on the direct route are the two limestone formations, the lower including Niagara and Helderberg, and the upper the carboniferous; and, from the great extent of level country, I was unable to see the intervening rocks.

I had an opportunity of examining the rocks on the northern and northeastern shores of the southern peninsula of Michigan, but my observations were too cursory to admit of any thing like a connected view of them. The limestones of the Helderberg series, principally the corniferous and Onondaga masses, form the rocks of many of the bays and harbors; characteristic fossils of these masses being recognizable in those examined. At Mackinak, the upper part of the Onondaga salt group, and possibly a small portion of the water-lime group, form all the rocks seen. The former is partially altered from its usual characters in New York, some parts exhibiting large angular cavities, the whole appearance being that of a vesicular mass; and had the cavities been spherical instead of angular, it would have been referred to igneous origin. This mass being isolated, renders it difficult to trace its connection with those appearing to the south and east of it; but from its great similarity to the salt group of New York, and from its apparently passing beneath those representing the Helderberg series, no doubt remains as to the propriety of this reference.

The exhibition of strata along the line of the section given, illustrates some very interesting points in the geology of our country, and proves the existence and order of succession in certain rocks, and their equivalents over wide areas; offering us facts which will still further enable us to solve the problem of the condition and character of the ocean during the earlier geological periods.

The great extent of almost undisturbed strata affords an opportunity for the most satisfactory investigations, throughout all this country. The anticlinal axis which is crossed by the section near Cincinnati, is an important feature. By the elevation of this axis, the higher rocks have been removed, and the two great coal basins of Ohio and the Wabash valley (formerly in all probability constituting one) are thus separated from each other. This axis extends in a direction northeast and southwest; and passing along the western part of Ohio, and crossing Lake Erie near its western extremity, it gives origin to the numerous islands of this part of the lake. It extends onward into Canada, and I understand from the Messrs. Rogers, that they have traced it far northward in that province. To the southward it passes through Kentucky and Tennessee, and at Frankfort, in the former State, elevates the Trenton and birdseye limestones above the level of the river.

The section crosses a synclinal axis which runs nearly parallel to the great anticlinal one, but its extent is unknown to me. The Wabash flows in this depression, which brings the coal-bearing strata below the level of the Ohio river, at its junction with the former. From this point the strata are seen to rise to the westward as far as the Mississippi, but beyond little is known of them. From the occurrence of extensive coal deposits in Missouri, it may be presumed that the strata decline to the southwest, but I have no data from actual observation on which to found an opinion.

From the necessarily hasty examinations made during this tour of exploration, which was extended over a large area, it was impossible to give that minuteness of detail, which is desirable before the subject can be considered complete. All that was attempted was to trace the great groups of New York westward, and, if possible, to identify them with those known by different names in that part of the country. If any light has been thrown upon this question, or if only some few points of identity have been established, the object will have been accomplished. In this vast field there is room for all the laborers that can be found for half a century to come, and I doubt not, from the numerous and efficient observers now at work in this region, upon their native or adopted soil, that all the most important details will soon be wrought out.

From the want of a well-defined and acknowledged basis in the West, it would always have been difficult, if not impossible, to establish the identity from that direction eastward, and it required a knowledge of the New York rocks, in their wide geographical range and undisturbed position, to settle satisfactorily the place of the western rocks.

From the facts here stated the conclusion seems unavoidable, that the character of fossils is, or may be, as variable as lithological characters; in fact, that the species depend in some degree upon the nature of the material among which they lived. Fossil characters, therefore, become of parallel importance to the lithological; and, in order to arrive at just conclusions, both must be studied in connection, and localities of proximity examined. In the case of the Hudson river group of shales and sandstones, in passing from New York to Ohio, the lithological character is almost entirely changed; and at the same time also the most prominent and abundant fossils are unlike those of the group in New York. More careful examination, however, reveals the fossils which characterize this group at the East, and also at the same time some obscurely similar lithological characters. Similar lithological changes, accompanied by like changes in fossils, occur in more limited districts within the State of New York.

The most marked and important changes, however, appear to be in the higher rocks of the New York system. The Hamilton group and Marcellus shale, which in New York have a thickness of one thousand feet, have diminished to one hundred where last examined; and from being the group most prolific in fossils, as it is in New York, it has become entirely barren of them. The rocks forming the Portage and Chemung groups, which in their greatest developement in New York are scarcely less than three thousand feet in thickness, and in Pennsylvania much more, have, in Indiana, diminished to as many hundred. The upper of these groups, from being extremely fossiliferous, has become almost destitute of these characters, so that, at the furthest extreme examined, they furnish but an equivocal guide. In these groups, lithological character is more persistent than fossils, and it requires a knowledge of the superposition to identify them satisfactorily. The greater thickness of these sedimentary deposits, and the greater developement of fossils occurring at the same point, proves the organic forms to have flourished in a littoral position; and beyond these points, where the thinning of the strata indicates a greater distance from the shore, the fossils diminish, and at the more distant and deeper points are not found at all. There is no evidence of denudation in these instances, and if there had been, the parts left would have retained the same fossils—had it ever contained them—as they do further east.

Throughout that part of the ancient ocean now occupied by Ohio, Indiana, Michigan, Illinois, and even to the west of the Mississippi, there appears to have been comparatively a small number of living forms existing from the period of the final deposition of the Helderberg limestones, to the commencement of the carboniferous period; while in New York, during the same period, there were a greater number of forms and individuals than in all the preceding periods. Without desiring to diminish the value of fossil characters as means of identifying strata, it must still be acknowledged, that similar conditions in the bed of the ocean, and, apparently, similar depth of water, are required to give existence or continuation to a uniform fauna; and when we pass beyond the points where these conditions existed in the ancient ocean, we lose, in the same degree, the evidences of identity founded upon fossils. Some species it is true have lived onward through successive depositions, often of very different nature; yet, at the same time, these may not have had a very wide geographical range. In the case before us, some species have lived during the deposition of all the rocks from the Hamilton through the Chemung groups, and yet they have never extended themselves as far westward as Ohio and Indiana, although the nature of the deposits there was as favorable to their existence as in New York.

For the distance of one hundred or two hundred miles from the shores of the present continents, the forms may be similar,—

we know not but they are — still, who can say what changes may occur, or whether any exist in the depths a thousand miles from land? From the nature of sedimentary deposits it can be only the finer parts that ever reach to great distances from their origin; and, reasoning thus, the fauna of the deep and distant parts of the ocean, if any exist, would be uniform, not being liable to destruction or change of condition from the rapid invasion of variable deposits like those near the shore. The deposition of a coarse sandstone or conglomerate succeeding to a shaly mass, would in all probability destroy the greater number of living forms as far as it extended. But at the same time, the finer materials produced by the same cause, would extend far beyond the limits of the coarser, and thus approximating in some degree to the lower mass, the fossils might be continued long after they were destroyed at another point.

One of the most interesting changes in the products on going westward, is the great increase of carbonate of lime, and the diminution of shaly and sandy matter, indicating a deeper ocean or greater distance from land. The source of the calcareous deposits is thus shown to have been in that direction, or in the southwest, while the sands and clays had their origin in the east, southeast, and northeast, producing a turbid condition in the waters of these parts during long intervals, which was unfavorable to the production of calcareous matter, and the formation of chemical deposits. In New York we are evidently upon the margin of this primeval ocean, as indicated in the character of the deposits as well as organic remains; the southwest unfolds to us that portion where greater depth and more quiet condition prevailed.

Note. In the paper published in the American Journal of Science, I inadvertently said, that the *Catenipora* was found only in the Niagara limestone, though I had previously obtained it from the Clinton group, but from its character I was inclined to refer it to a different species from the *C. escharoides.* The two are however identical, presenting no greater differences than are often seen in this fossil from the same rock and locality. Notwithstanding this fact, however, the *Catenipora* is far from being an abundant fossil in New York, and among the thousands of specimens of rocks and fossils in the State collection—the results of the geological survey—the *Catenipora* appears but from three positions, and one of these seems to me equivocal. The lowest position is the Clinton group, from which *one specimen* only appears, *two* being all that are known to have been found. The second position is the upper part of the Niagara limestone, where it is common, and occurs in numerous localities. The third position is from what is considered the water-lime group. But in order that this fact may be fully appreciated, it should be known that wherever the *Catenipora* appears in the water-lime group, the Onondaga salt group has nearly thinned out, thus bringing the Niagara group very near the water-lime. At some localities of this kind, the *Catenipora* is in a mass, which at Schoharie is known as the "Coralline limestone," and which is separated from the water-lime (as characterized by fossils) by twenty-five feet or more of a soft ash-colored rock destitute of fossils. This coralline limestone contains no fossils in common with the true water-lime above. It rests upon a green shale with iron pyrites, which, from the absence of the Medina sandstone and conglomerate, is succeeded below by the Hudson river group.

The point to be decided is, whether the green shale, containing iron pyrites, is the representative of the Clinton, or of the Onondaga salt group. If the former, then the "Coralline limestone" holds the place of the Niagara limestone, and must be considered its equivalent; but if the latter, then it is a part of the water-lime group. But in all instances which I have known, where the *Catenipora* occurs in the so called water-lime group, there has been an extreme thinning out of the inferior groups, so that this one and the Hudson river group are brought within a short distance of each other. I might observe, also, that there are several species of fossils in the "Coralline limestone" which appear to be identical with some in the Niagara group, and which are not found in the water-lime group where the intermediate rocks are largely developed.

In the paper before alluded to, the name Niagara limestone was sometimes used as synonymous with Cliff limestone. It will be seen, however, from other parts of the same, that the Niagara limestone forms only a part of the Cliff, and of course could not have been intended to apply to the whole, which is distinctly stated to be composed of several of the New York rocks and groups. That portion representing the Niagara limestone rarely furnished any other fossils than *Catenipora*, *Favosites*, and some other corals. The *Pentamerus oblongus* occurs in the same association and but little separated from these, and never associated with *Pterinea carinata* and *Cypricardia* of the blue limestone, or Hudson river group.

Explanation of the Sections. Plate XII.

The Section No. 1, commencing at Cleveland, exhibits as the lower rock the dark-colored bituminous shales of Ohio, which are the continuation of the Hamilton group and Marcellus shale of New York, the latter being more persistent than the former, and the more important part of the whole. This shale appears on the lake shore a few miles west of Cleveland.

The ascent to the summit is over the Portage and Chemung groups, which are much diminished in thickness compared with the same in New York. From the Chemung we pass directly to the conglomerate, and thence to the coal and associated rocks.

In descending southward the same rocks appear in the inverse order, and near Columbus the limestones representing the Helderberg series are seen passing under the Marcellus shale. The limestones of the Helderberg series are separated from the Niagara group by a thin mass of water-lime, and from these we descend over greenish-gray impure limestones to the rocks representing the Hudson river group, seen along the Ohio at Cincinnati, Maysville, and other places.

Pursuing the section still westward, the same order holds good among the rocks, till we arrive at the termination of the Chemung group, where, between this and the conglomerate, we find a gray sandstone with intercalated beds of öolitic limestone. This is succeeded by a thick formation of gray fossiliferous limestone, which passes beneath the conglomerate, and reappears again from beneath the great Illinois coal field as we approach the Mississippi river.

The Section No. 2, exhibits the order of succession among the rocks and groups, composing the New York system. This section is given in order to afford means of comparison with the western rocks, those of New York being made the standards of reference. By comparing these sections, it will be seen that several of the formations thin out or are greatly diminished at the West, and that the lowest rock visible along the line of the section is the Utica slate, which appears at the level of the Ohio river. This section terminates with the Portage and Chemung groups, which have diminished in thickness, and become more similar to each other, in Ohio. The space between the termination of this section and the commencement of the other, along the shore of Lake Erie, present only rocks of the Portage group.

Description of several species of Fossil Plants, from the New Red Sandstone Formation of Connecticut and Massachusetts. By Prof. Edward Hitchcock, LL. D., *of Amherst, Massachusetts.*

In the towns of Woodbury and Southbury, in Connecticut, near the Housatonic, there exists a series of rocks, almost precisely similar to those which occupy the valley of Connecticut river. We find associated there, shales, sandstones, limestones, and trap rocks, with all the organic remains found along the Connecticut; nor can there be a doubt, that it is precisely the same formation, on a limited scale, as that in the Connecticut valley.

About thirteen years ago, I gave an account, in the fourteenth volume of the American Journal of Science, of a portion of the fossil trunk of a tree, in the cabinet of Dr. Smith, of Southbury. It was eight or ten inches in diameter, and several inches long; completely silicified, and showing a difference of colors between the bark and the inner portion of the tree. It was obtained by a workman, who mistook it for a stump, in a swamp, and battered his axe upon it, and in revenge almost ruined it. Recently I sent a small piece of this wood to Prof. Bailey, with the request that he would examine it microscopically. The result of his investigation is highly satisfactory, and I give it in his own words.

"I examined, with great interest, the fossil tree, in whose branches probably once sported some of your wild fowl of the New Red sandstone period. The paucity of organic remains in this formation, made me very desirous to ascertain, if possible, the nature of the wood. By means of thin splinters, coated with Canada Balsam, I was able to examine it almost as well as if I had slices prepared by a lapidary.

"The facts ascertained were these:

Facts.	*Conclusions.*
1. It presents medullary rays.	1. Therefore *Dicotyledonous.*
2. In the space of an inch there are no concentric rings.	2. Therefore of rapid growth, or produced in a warm climate.

3. The cross section shows the mouths of the woody fibre to be of nearly uniform size, and no large openings belonging to dotted ducts, or spiral vessels, can be seen.	3. This agrees with *Coniferæ*, and the cross section agrees *strikingly* with the structure of this tube.
4. The longitudinal section shows straight parallel tubes of uniform size, and occasional medullary plates.	4. This is like *Coniferæ.*
5. These tubes do not show decidedly the peculiar glands which distinguish the *Coniferæ*, but present various figures, from the formation within them of microscopic agates.	5. If this tree was, as I am inclined to believe, one of the *Coniferæ*, the apparent absence of the glands may be accounted for by their obliteration during slow petrifaction. The agate-like arrangement of the silica in many portions favors the view.

"Plate XIII, fig. 1, shows the wood, as seen under a low power of my microscope. A higher power showed nothing in addition. *A* is a cross section, showing the mouths of several radiant rows of fibre, and one medullary plate, *a a*. *B* is a longitudinal section, presenting no peculiar markings. *C* is also longitudinal, and presents at *a* exactly the form of a glandular disc of coniferæ, but this is accidental, being produced by a microscopic agate; other forms of these agates are shown at *b b*. I would be glad to learn something more of this tree, its particular locality, whether it presents, on a larger piece, any concentric annual rings, whether it has a pithy centre, &c."

These results by Prof. Bailey, will not, indeed, afford any decisive evidence as to the exact position on the geological scale, of the formation containing this fossil tree, for the *Coniferæ* extend through nearly all the fossiliferous rocks. But such facts can hardly fail to be ultimately serviceable, in perfecting the geology of the Connecticut valley.

In blasting a large bowlder of dark gray sandstone, on Mount Holyoke in Massachusetts, for the foundation of the new church in Hadley, several fossil plants were brought to light; but all of them were destroyed except the fragment shown of the natural size in Plate XIII, fig. 2, which was kindly presented to me by the architect, Col. Warren Howland. I immediately recognized it as a *Tæniopteris*, showing only the views on one side of the midrib, the other side having been broken off as the stone was split. Very probably it is the *Tæniopteris vittata*, figured by Prof. Brown, in his "*Lethæa Geognostica*," Tab. XII, fig. 2. Col. Howland informs me that some of these impressions were nearly two feet long.

It is interesting to know that the *Tæniopteris vittata* is one of the characteristic fossils of the new red sandstone, so that I feel as if the discovery of this plant in the valley of the Connecticut, ought to strengthen the opinion which I have for some time maintained, that the sandstone of that valley belongs to the new red sandstone of geologists.

Dr. James Deane, of Greenfield, has recently presented me with a few small fragments of a fossil plant, found in the shale of the same formation, in Montague, in Massachusetts, where a few years since an effort was made to discover coal. These are shown of the natural size on Plate XII, figs. 3, 4, and 5. Though imperfect, I can hardly doubt but they should be referred to the *Voltzia;* another characteristic plant of the new red sandstone.

Description of the Oxide of Tin found at the Tourmaline Locality, Chesterfield, Mass. By J. E. Teschemacher, *of Boston.*

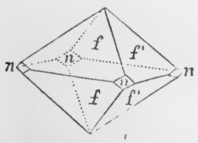
In the edition of Mohs' Mineralogy by Haidinger, it is stated, that small groups of black twin crystals of oxide of tin had been discovered in the Albite rock of Chesterfield, Mass.; and in Dana's Mineralogy it is stated, that a few crystals of tin ore had been found there: but as no particular description has been given, and as most mineralogists had been unsuccessful in their search after this interesting mineral, many suspected that some error existed, and that tin had not been found in that locality.

Having been fortunate enough to find a few very perfect crystals, in specimens from this place, I presume it will be interesting to offer a description of their physical qualities, by which all doubt on this subject will be set at rest. But I will first read an extract from a letter of Mr. A. A. Hayes, to whom I submitted a portion for examination. After detailing his proceedings, he observes:

"From these experiments it appears that the mineral is a nearly pure oxide of tin, its hardness and closeness of texture, as indicated by its high lustre, exceed those of any specimen I ever examined. You have the satisfaction now of settling the question which has been so long agitated in relation to oxide of tin having been found in Massachusetts."

Its physical characters are as follows: color black, lustre almost metallic, with external iridescence; powder of streak pale clay color; some of the very minute crystals are translucent, and of that peculiar brown color so well known in oxide of tin; the quantity of crystals found does not exceed half a dozen, the largest of which is one line at the base of the pyramid. Form, an obtuse octahedron, with a square base, formed by the second modification of Phillips, in his paper in the second volume of the Transactions of the Geological Society of London, which answers to modification *f*, of Brooke. On the minute crystals, Phillips's fourth modification is very distinct; it answers to Brooke's *modification*, but the planes of *n* are not sufficiently clear for measurement.

I obtained the following measurements with the reflecting goniometer, which are sufficiently approximative to those of Phillips, to leave no doubt on the form, considering the usual difficulty of measuring crystals of tin.



			Phillips.
f on *f'* on adjacent planes of pyramid,	121.25′	"	121.40′
f on *f* over summit, . . .	92.50′	"	92.55′
f on *f* over the base of the pyramids,	87.15′	"	87.5′

I did not find any twin crystals, as mentioned in Mohs.

In reference to the above, and the mineral *Pyrochlore* found by Prof. Shepard at this locality, Mr. Hayes observes:

"There is an interesting feature in this connection disclosed by the examination made of the Titaniferous Tin and Cerium oxides. The titanic oxide does not *probably* unite with the oxide of tin, and our mineral, (pyrochlore,) *probably* consists of oxides and silicates crystallizing in common."

On the Age of the Coal Rocks of Eastern Virginia. By William B. Rogers, *Professor of Natural Philosophy in the University of Virginia.*

The formation here referred to, overspreads parts of Chesterfield, Powhatan, Amelia, Henrico, Hanover, and Goochland counties, lying in basins of granite and gneiss, the principal coal seams being separated by only a few feet, and sometimes by but a few inches, of carbonaceous shale from the floor of primary rock. In some places near the eastern margin of the field, where it has been most extensively explored, the thickness of this group of strata is about eight hundred feet, but towards the centre of the principal basin it is probably somewhat greater. Throughout much of this depth the strata consist of coarse grits, composed of the materials of granite, so little worn as to have the aspect of this rock in a decomposing state. The coal, which in the northern parts of the field is divided into two and sometimes three distinct seams, separated by considerable intervals of slates and grits, but all comprised within the lowest one hundred and fifty feet of the series, is in the more productive region, south of the James river in Chesterfield county, collected together into one immense stratum, which, though of very variable thickness, may be generally stated at from twenty to forty feet.*

The curious circumstance, of the grits and coal-bearing strata of this region resting immediately on a floor of granitic and gneissoid rock, appears early to have attracted notice, and, connected with the fact, that the coarser sandstones are but the recemented materials of the adjoining primary masses, almost unmarked by aqueous wearing, seems to have led to the prevailing belief of the very high geological antiquity of these deposits. Such considerations, and others, chiefly lithological, would appear to have formed the grounds upon which the distinguished pioneer

* For a particular account of the boundaries and contents of this coal field, the composition of its numerous varieties of coal, and other details, see Reports of Geological Survey of Virginia, for 1836, 1840. Also, "Memoir of a Section passing through the Bituminous Coal Field near Richmond," by Richard C. Taylor. A more copious and accurate account will hereafter appear in the Final Report on the Geology of the State.

of American Geology, Maclure, founded his reference of this remarkable series of grits and carbonaceous strata, to the period of the old red sandstone. More recently, Mr. R. C. Taylor, in an interesting paper relating to this region, in the Transactions of the Geological Society of Pennsylvania, expresses himself as "rather inclined to assign this independent coal formation to the transition carboniferous deposits, than to the secondary class," on the ground of the absence of any "analogy" between it and the latter, "throughout the whole series of superincumbent strata."

The further explorations in this region, made in the course of the Geological Survey of the State, aided by new and extended mining operations, having brought to light, more clearly than before, many interesting organic remains, chiefly of vegetable origin, have afforded me the opportunity of accumulating important data for determining the epoch of this isolated and remarkable coal formation. In the absence of such a guide, and judging by lithological indications alone, perhaps no more probable conclusion would have been reached on this subject, than that of the able geologists whose names have just been mentioned.

These vegetable remains, *as a group*, bear a striking resemblance to those which accompany the Öolite coal of Brora, Whitby, and other European localities. Some of them, as, *Equisetum columnare*, *Calamites arenaceus*, *Pecopteris Whitbiensis*, *Pecopteris Munsteriana* and *Lycopodites uncifolius*, are, I think, specifically the same with the European fossils, while the rest, among which are *Tæniopteris magnifolia*, an unnamed *Pecopteris*, and two or perhaps three species of *Zamites*, are very closely allied to certain species of the same genera, found in connection with the Öolite coal of Yorkshire, Sunderlandshire, and other places in Europe.

The most abundant of these remains are, the *Equisetum columnare*, also said to exist in great profusion at Brora and Whitby; a large species of *Zamites?* hereafter to be noticed; and a magnificent *Tæniopteris*, (*T. magnifolia*,) very closely analogous to *T. vittata* and *T. scitaminea* of the Yorkshire and Sunderlandshire formation. These four being found in vast numbers immediately upon, and interlaminated with the coal, where it is slaty, would appear to have furnished the principal materials of the stratum. No remains bearing any resemblance to *Stigmaria* have been discovered either in the soft carbonaceous slates beneath, above, or in the midst of the seams, or in the other slaty and gritty strata of the series.

With such a striking agreement, as regards not only the general character of the vegetation, but the individual plants belonging to the rocks now under consideration, and those of the Öolite coal of Europe, it can scarcely be doubted that they were formed during the same or very nearly the same geological period, and I therefore feel no hesitation in referring the *coal of Eastern Virginia* to a place in the *Öolite system on the same general parallel with the carbonaceous beds of Whitby and Brora*—that is, in the lower part of the Öolite group.

This determination possesses, I conceive, no small degree of interest in its connection with our geology generally, inasmuch as it supplies a very important link in the great geological succession of formations, which had not previously been discovered anywhere within the United States. Nor is its importance less, when connected with the striking discovery of Capt. Grant, of an Öolite coal-series in the opposite hemisphere, near the mouth of the Indus, some of the fossils of which appear to be almost identical with plants, from the Virginia coal rocks, hereafter to be described.* With these discoveries in view, it can scarcely be doubted that the *fossil flora* of even the *middle geological periods* has sufficient uniformity of character, even in opposite parts of the globe, to furnish a very useful guide in the comparison and identification of great geological groups.

Of *Animal remains*, so abundant in the Öolite generally, the only traces yet discovered in the Öolite coal series of Virginia consist of *teeth*, apparently *Saurian*, recently found by me in and a little above one of the coal seams in the northern part of the district, and the scales and sometimes entire impressions of a slightly *Heterocercal* fish, referred to, doubtingly, by Mr. Nuttall,†

* See "Memoir to illustrate a Geological Map of Cutch." By C. W. Grant, Esq., Trans. Geol. Soc. Lond., Vol. V., 2d series.

† See Trans. Acad. Nat. Sciences, Philadelphia. Vol. 2.

many years ago, and lately examined and named by our able icthyologist, Mr. Redfield.

The coarser rocks, lying above the carbonaceous strata, and forming the greater part of the thickness of the series, contain very few organic remains, and those in so imperfect a condition as to have little or no value for purposes of comparison. There are, however, strong reasons for believing that these strata, by a gradual transition, pass upwards into the series of felspathic sandstones, described in my Report of the Geological Survey of Virginia for 1840, under the title of *Upper Secondary Strata.* The latter, considered by Messrs. Taylor and Clemson, as "of secondary origin, perhaps coeval with the Öolites," have since been referred by myself and Prof. H. D. Rogers, to the *upper part* of the Öolite series, so that this great division of the geological column, though still perhaps very imperfectly represented in the United States, comprises a thickness of considerably more than one thousand feet of strata.

I may here incidentally remark, that certain fossils (*Posidonomya Keuperi? &c.*) which I have recently found in a particular division of the new red sandstone (*Middle secondary*) of Virginia, have led me to infer the existence in that formation, of beds corresponding to the *Keuper* of Europe. A more particular account of this discovery is reserved for a future occasion.

The following descriptions of some of the principal fossil plants, found in connection with the Öolite coal of Eastern Virginia, are the results of a careful comparison of the specimens with the figures and descriptions of analogous fossils, in Sternberg, Brongniart, Bronn, Lindley and Hutton, Phillips, and the Memoirs of Murchison, Grant, and others relating to the subject. These, with others not yet ready for the press, will, I trust, fully sustain my conclusion as to the age of the remarkable coal-formation under consideration.

The details which they include, though inconsistent with the elegance of technical description, together with Plates XIII and XIV, will, it is believed, facilitate a just comparison of these fossils with those of the Öolite coal-formation elsewhere.

Fossil Plants of the Öolite Coal Rocks of Eastern Virginia.

Equisetum columnare. *Brongn.*

Oncylogonatum carbonarium. Koenig.
Equisetites columnaris. Sternberg.

The fossil referred to under this title, occurs very abundantly in certain slaty and argillaceous rocks met with at nearly all the openings in the coal-fields, both north and south of the James river, and appears to have formed one of the chief sources of the material of the coal beds. The specimens in the slaty rock are generally flattened out parallel with the laminæ of the slate, and from the conversion of the vegetable matter into coal, give rise to alternations of coal and slaty material, sometimes as numerous as thirty in an inch. On one of these masses of slate in my collection, there is a beautiful impression of a part of the *Equisetum*, about fifteen inches long, and where widest, seven inches broad, comprising ten distinct articulations, the intervals of which regularly diminish from one extremity of the fossil to the other. Specimens of this fossil are also met with in a dark bituminous clay, and a light brownish, soft sandstone, both of which occupy a place near the coal. In these the rotundity of the stems is pretty well preserved, the rocks imbedding them being destitute of the laminated structure.

The flattened as well as the convex impressions agree exactly with the figures appended to Murchison's Memoir on the coal field of Brora, Trans. Geol. Soc. of Lond., Vol. II, Part II, and correspond in every particular with the description of the Brora fossil as given by Koenig in this memoir. The "acute regular furrows of various lengths, gradually diminishing in width, and running out into linear grooves," and "the elevated rays or ribs having a pretty acute ridge, and gradually tapering into a fine, more or less lengthened raised line," referred to by Koenig, as impressions produced by the flattened stem of the *Oncylogonatum*, and represented in figures 3 and 4, of Mr. Murchison's Memoir, are facsimiles of the Virginia fossil, as it occurs in innumerable layers in the slaty rocks, or is impressed on the parting surfaces of some varieties of the coal. Nor is the resemblance less perfect between the uncompressed form of the Brora fossil as represented in figures 1 and 2 of the Memoir, and the cylindrical jointed stems marked near the joints with similar grooves and ribs, already alluded to as occurring in certain soft sandstones and argillaceous beds in the Virginia localities. I have therefore no hesitation in considering the Virginia fossil as identical with that of Brora, as well as with that referred to by Prof. Phillips in his Geology of Yorkshire, as occurring in the sandstone at High Whitby, and recognized by him to be the Brora fossil. Guided by the authority of Brongniart, who describes specimens from Brora, Whitby, and other European localities, I shall hereafter speak of our fossil as the *Equisetum columnare*.

In all the British localities of this fossil, as Whitby, Haiburne, Wyke, and Brora, it occurs in connection with carbonaceous beds, appertaining to the *Lower Öolite*. In the neighborhood of Balbronn, Gemonvel, Studtgard, and other localities on the Continent, it is found in geological connections less certainly determined, but which Brongniart infers to be the same as those in which it occurs in Great Britain. In closing his account of this fossil, Brongniart says: "In England, where the secondary formations have been so well studied, no trace of this plant has yet been found in the lias, or in the more ancient beds, or in the Oxford clay and more recent formations; nor does any thing in the Stonesfield limestone or Tilgate limestone, indicate the presence of this plant, *which we may therefore consider as characterizing the lower beds of the Jura limestone*" (*the Lower Öolite*).

Equisetum arundiniforme.

The fossil for which the above title is provisionally proposed, bears a close resemblance to the stem of a common reed, bruised and flattened by pressure. The most perfect specimen in my possession is on a light gray, slightly micaceous slate. The stem, which is flattened out, is fifteen inches long, and two and a half to three inches wide, divided by joints about four inches asunder.

The surface, though entirely destitute of regular ribs or striæ, is marked, especially in the vicinity of the joints, with low, short, triangular plicatures, apparently due to compressing action. At the joints, which are beautifully distinct, and over much of the surface, the slaty matter is covered with a siliceous coating of a lighter color and much greater hardness than the body of the rock, derived apparently from the joints and epidermis of the plant.

The lower and toothless joint, in Plate XXXI, fig. 3, Sternberg, representing *Equisetites acutus*, bears a strong resemblance to this fossil, as do also the reed-like stems represented along with impressions of *Zamites heterophyllus*, in Plate XLIII, figs. 4 and 5, Sternberg.

Calamites arenaceus. *Brongn.*

The fossil referred to by this title is frequently met with in the coal rocks of Eastern Virginia, occurring both in the dark laminated slates, and in the soft, bluish-gray sandstones. In the former position it is generally very much flattened, from compression between the layers of slate; in the latter it is often quite cylindrical, being found in an erect posture in the rock.

On comparing some good specimens in my collection with Brongniart's figures and description of *C. arenaceus*, I am convinced that our fossil is of this species, or one very closely allied to it, and that it differs in many important points from *C. Suckowii.* The calamite from Eastern Virginia, forwarded by Prof. Silliman to M. Brongniart, and by the latter figured as *C. Suckowii* was obviously, and as he himself confesses, a very imperfect one, and as will be seen by inspecting his drawings, differs in many respects from the other specimens, referred by him to the same species, all of which were derived from the true carboniferous formation. From Brongniart's drawing of the Virginia specimen, and his statement that it is nearly or entirely *destitute of tubercles* at the joints, in which it strikingly differs from the true *C. Suckowii*, and agrees with the *arenaceus*, I am fully convinced that the fossil figured by him as a variety of *C.*

Suckowii, is the same as that I am now describing, and is the true *Calamites arenaceus*.

It may, perhaps, be conjectured, without doubting the great skill of this illustrious naturalist in vegetable Palæontology, that the specimens from Wilkesbarre and Richmond, being presumed by him to have come from the same geological formation, and the very imperfect condition of the Virginia specimen disguising its peculiarities, he failed in bestowing such attention on the subject as would have assured him that the two were of different species.

According to Brongniart, the *C. arenaceus* occurs associated with *Equisetum columnare*, near Studtgard.

Calamites planicostatus.

The fossil here referred to is usually met with in the slaty beds containing the *Equisetum columnare*, and is, in some localities, quite as abundant as that plant. The best characterized specimen in my collection has the appearance of a flattened stem, exhibiting several distinct articulations, all entirely devoid of tubercles. Throughout its whole length, this impression is marked by shallow parallel grooves, slightly deepening towards the joints, and distant one from another from the fifteenth to the twentieth of an inch. These grooves are generally prolonged across the joints, so as to be continuous throughout the neighboring divisions of the stem, suffering only a slight flexure and lateral displacement as they cross the articulations, and returning again to the original line. The ribs or ridges between the grooves are smooth and flat, excepting near the joints, where they are slightly but irregularly convex. At many of these joints, are seen small circular scars, like the points of insertion of leaves, arranged at intervals of about half an inch. One or two extremely fine striæ may generally be traced along the middle of each rib.

From the general flatness of the impression, and the great shallowness of the furrows, it might at first be readily taken for a large striated leaf; but, upon removing the coaly film which conceals the articulation, the jointed and stem-like nature of the fossil is indistinctly shown. The great thickness of the coaly layer adjoining this impression upon the surface of the slate, and the number of such impressions found in the layers of a fragment of the rock only one or two inches thick, imply that the hollow stem of the plant which produced them, was extremely thin, and easily compressed. Whether it was of the same genus with the plants whose fossil relics have been arranged under the title of calamites, it would be impossible as yet to determine. As far as may be inferred from external appearances, it would seem to be referable to that group. Ranking it, therefore, for the present, with the long list of *doubtful* fossils included under this generic head, I propose the specific name of *planicostatus*, as descriptive of the remarkable flatness of its ribs.

Tæniopteris magnifolia.

The impressions of this superb plant are found in great numbers in some of the dark gray slaty layers and ferruginous bands above the coal, and even upon the surfaces or partings of certain varieties of the coal itself. This fossil retains so perfectly the delicate markings of the original frond, that I have been able to compare it satisfactorily with the other species of the same genus, figured and described by Brongniart, Phillips, Lindley and Hutton, and Sternberg, and have thence been led to consider it as a new species. The particulars in which it differs from the *Tæniopteris vittata*, Brongn. and *T. scitaminea* (Presl.) Sternberg, the two species which it most nearly resembles, will appear from the following description:

1st. *The form of the frond.* Although among my specimens there is no large frond, in which both the extremities are entire, the numerous fragments of fronds, exhibiting the ends as well as the middle portions of different leaves, enable me very satisfactorily to trace the figure of the frond, in an advanced stage of growth. This may be described as oval-lanceolate, but with this peculiarity, that while the upper or free end is formed by a gradual curving of the margin, from the wide part of the frond toward the end, so as to present a very regular and nearly elliptical sweep, the lower extremity tapers towards the petiole, in a somewhat irregular and undulating manner, and is greatly reduced in width before it terminates. Our fossil thus agrees with the *T. vittata* in the elliptical outline of the upper half of the frond, but differs from it in the undulating margin and more triangular form of the part next the petiole. It is also wider in proportion to its length. It is at once distinguished from the *T. scitaminea*, which in other respects it very closely resembles, by the apex of the latter having a reëntering, cordate curvature.

2d. *The size of the frond.* A comparison of the smaller and more perfect fronds with fragments of the larger ones, often amounting to one half or three fourths of the whole, has enabled me to supply the outline of the deficient portions of many of the latter, and has thus afforded data for measuring a number of the fronds. The following are the dimensions of three, greatly differing in size:

		Inches.
Frond A.	Breadth,	2.4
	Estimated length by several fragments,	14.
Frond B.	Breadth,	4.
	Estimated length,	24.
Frond C.	Breadth,	6.4
	Estimated length,	40.

The breadths here recorded were all carefully measured upon the specimens. The length of A, was deduced from the measured length of a fragment twelve inches long; that of B, from a fragment twenty inches long, and that of C, from several fragments, from six to twelve inches long. The estimated lengths of A and B, are probably a little less than the true lengths.

3. *The Midrib and Petiole.* The Midrib is quite robust, having, in some of the larger impressions, a width of from one third to one half an inch, but gradually tapering towards the upper end, it becomes extremely slender at the apex. On the upper side it is marked by a somewhat deep groove and numerous parallel striæ. The Petiole is thick, rounded at the end, and about one seventh the length of the frond. This slenderness of the midrib towards the upper end, forms another feature of distinction between our fossil and the T. *vittata*, as figured by Brongniart, and in this particular gives it more resemblance to the drawing given by Lindley & Hutton of T. *major*.

4. *The Nervures.* As in the T. *vittata*, T. *scitaminea*, and a few other species, the nervures of our fossil are nearly or exactly at *right angles* to the midrib. They are, however, *far more delicate and numerous than in T. vittata.* Moreover, after a careful examination of the nervures of more than twenty fragments, I have been unable to discover more than three or four instances of their bifurcation, either near the midrib, or at any other part of their length; while, on many large and distinct specimens, not a single example of bifurcation could be found. *Simplicity of the nervures* is, therefore, to be ranked as one of the characters of our fossil. In the T. *vittata*, on the other hand, according to Brongniart, "the nervures are sometimes simple, sometimes bifurcated either towards the base, the middle, or near the extremity;" and in Brongniart's figure, the bifurcated nervures are as numerous as the simple ones, the two being arranged alternately. In Sternberg's definition of the species, a similar frequency of bifurcation is implied by the words "*venis horizontalibus furcatis, cum simplicibus alternantibus.*"

5. *The position and size of the supposed points of fructification.* On many of the fronds of the Virginia fossil an irregular row of circular depressions is seen, on each side of the midrib, and not unfrequently on the midrib itself. These hollows would seem, as in the *vittata*, to mark (according to Brongniart) the position of the roundish groups of capsules. They are, however, much larger than in that species, being from one sixth to one fourth of an inch in diameter, and are placed at unequal intervals asunder, and at rather varying distances from the midrib.

The peculiarities above described, especially the form and size of the frond, and the almost invariable singleness of the nervures, would seem to furnish ample reasons for regarding the Virginia fossil as distinct from either the T. *vittata* or T. *scitaminea*, although nearly allied to both. Looking upon it as forming a new species, I have ventured to give it the title of T. *magnifolia.*

T. magnifolia. Frond, varying from one to six inches in width, and from seven to forty inches in length, curving elliptically towards apex, tapering with an undulating margin towards base, supported by a thick petiole about one seventh the length of the frond, and rounded off at the end. Midrib thick, marked on the superior side by a somewhat deep groove and numerous parallel lines; nervures perpendicular to midrib; simple, or very rarely bifurcated; parallel, distinctly prominent, and numbering, in the large frond, from fifty to sixty to an inch.

The *genus Tæniopteris*, entirely unknown in the carboniferous formation, first makes its appearance in the new red sandstone, and still later, forms, in the lias and öolite, an important and apparently characteristic group. The species most nearly allied to our fossil, namely, T. *vittata*, T. *scitaminea*, T. *major*, and T. *latifolia*, appear to be peculiar to the lower part of the öolite and the lias, either one or all of them being found in this geological position at Hoer, Neuewelt, Whitby, Scarborough, Stonesfield, and other localities.

Speaking of the *vittata*, Brongniart says: " This fern is one of the most common in the Jura formations, and may be regarded as one of the characteristic plants of our third period of vegetation. From a citation of localities, it appears that it has already been found in widely distant places, and that it is especially abundant in the Öolite marls of the coast of Yorkshire."

Pecopteris Whitbiensis. *Brongniart.*

Although fossils of the fern tribe are of very rare occurrence in the strata of which I am now treating, I have been fortunate enough to procure several specimens in a good state of preservation. These I find to be referable to three species, closely resembling, if not identical with species found in the lower part of the Öolite in Europe. The fossil referred to under the present head, corresponds so well with Brongniart's figures and description of P. *Whitbiensis*, that, notwithstanding a slight disagreement in one or two minor points, I cannot but regard it as of the same species.

The leaf is bi-pinnate, the rachis thick and smooth, the pinnæ oblique, opposite, straight, much prolonged, and tapering towards the apex. The pinnules are contiguous, but not confluent; protracted at the upper part of the base, contracted at the lower; they are arcuate-acute, but less so than in Brongniart's figure of

P. *Whitbiensis*. The main nerve, starting from the midrib nearly at right angles, bends gradually upwards, the nervules diverging slowly from this, or springing from the base near the central nerve, are once and twice furcated, and both they and the central nerve are very delicate. In most of these particulars, it will be seen that our fossil agrees precisely with P. *Whitbiensis*. The only points of difference seem to be, a somewhat less acute termination of the pinnules, their rather greater breadth in proportion to their length, and their more delicate nervation. These disagreements are, I presume, too unimportant to separate the Virginia fossil from the P. *Whitbiensis*, especially when so high an authority as Sternberg has united under this title three of Brongniart's species, presenting much greater diversities, namely, P. *Whitbiensis*, P. *Nebbensis*, P. *teneris*.

The importance of this fossil, in determining the age of the strata in which it is found, may be inferred from the statement of Brongniart, that "this plant is altogether peculiar to the Jura formation, and has no analogy with any of those which appertain to the true carboniferous system.

Pecopteris Munsteriana. *Sternberg*.

Of the fossil here referred to, I have met with but one specimen. This consists of a single pinna, with a full array of uncommonly large, and, in general, distinctly marked pinnules. The extraordinary size of the pinnules, and their proximity and mode of attachment to the rachis, might at first lead us to regard this fossil as identical with the *Pecopteris insignis* of the Yorkshire Öolite, described and figured by Lindley and Hutton; but a closer attention to the plan of nervation, and the form and size of the pinnules of the two, discloses very important points of difference. In the P. *insignis*, each nervure, at its junction with the middle nerve, very regularly divides into two branches. In the Virginia fossil, after this forking at the middle nerve, there occurs a further bifurcation of one or of both the branches thus formed. The pinnules of the P. *insignis* are larger than those of our fossil; they are, moreover, of a falcated shape, while those of the Virginia species are nearly or quite straight, and have an ovate termination. Among all the species of Pecopteris described and figured by Sternberg, Brongniart, and Lindley and Hutton, the P. *Munsteriana* is that with which our fossil most nearly corresponds. In the shape of the leaf, and its mode of attachment to the rachis, and in the peculiar plan of nervation, as shown in Sternberg's drawing of P. *Munsteriana*, the agreement is perhaps as close as could be expected, even in two specimens of the same species. The only point of difference between them, appears to be the greater size of the pinnules in the Virginia fossil. As, however, the disparity is not very great, and the smaller pinnules on the Virginia specimens are quite as large as the larger ones in Sternberg's figure, the inequality may probably be explained by difference of age or of position on the leaf.

According to Sternberg, the P. *Munsteriana* occurs at Bullenreit, near Baruth, in strata, referred to the *Lias*.

Pecopteris. . . . . .

This specimen consists of several incomplete *pinnæ*, evidently appertaining to a large Pecopteris, of a different species from either of the preceding. The *pinnæ* are straight, regularly tapering towards the extremity, nearly at right angles to the main stem, and closely crowded together. The pinnules arranged alternately on the opposite sides of the midrib, are nearly perpendicular to it, and are attached by the entire base, but quite separated one from another, having no connecting wing. The pinnules, near the base of the *pinnæ*, preserve a nearly uniform breadth, from the attachment to near the extremity, and are then very bluntly rounded off. Those more towards the end of the *pinnæ* are slightly tapering, curve a little upwards, and terminate acutely. A strong ridge marks the position of the middle nerve. Each pinnule is crowded with the impression of *Sori*, forming a row of dots, or of depressions, from six to twelve in number, on each side of the middle nerve; but in no part of the specimen can the nervures be distinctly traced. Of the various species figured, that which seems most nearly to approach our fossil is the *Pecop. obtusifolia* of the Yorkshire Öolite, as represented by Lind. and Hutton, plate CLVIII, figs. 1 and 16. According to the description of these authors, however, the Yorkshire fossil is a much smaller and more delicate plant than ours.

LYCOPODITES WILLIAMSONIS. *Brongn., Prodromus.*

Lycopodites uncifolius. Phillips's Yorkshire.

The fossil impressions referred to this title, comprising different portions of the plant, among which are the head or cone, correspond in almost every particular with the figure of *Lycop. uncifolius*, given by Lindley and Hutton, as copied from Mr. Williamson. "The one, and sometimes two, strongly marked ridges up the centre of each leaf," the "oppositely placed leaves, with the smaller ones between," the scales upon the stems, the cones with "the strongly marked rhomboidal spaces like scars," the peculiar claw-like form of the leaf, especially where full grown, are all distinctly exhibited in the Virginia fossil. Indeed the only points in which it seems at all to differ from the figure of L. *uncifolius* given by Lindley and Hutton, are, that it is smaller in all its dimensions, has apparently a less scaly stem, and has its small leaves less sharply pointed, and less curved than the Yorkshire fossil. Considering these minor differences as affording no sufficient grounds for ranking it as a distinct species, when in other respects the agreement is so striking, I do not hesitate to regard it as either identical with the *Lycopodites uncifolius*, or as a species closely allied to that plant.

ZAMITES OBTUSIFOLIUS.

The beautiful fossil, which I propose to designate by this title, is found along with the *Lycopodites*, above described, in a state of good preservation, in a dark-gray argillaceous slate, not far above the coal. It has the form of fragments of the leaf, or pinna, one of which, in my collection, though still incomplete, is about eight inches long. The impression of the midrib is nearly straight, gradually tapering towards the outer end of the pinna, and irregularly and rather finely striated. This, when widest, in the larger pinna above mentioned, is about one tenth of an inch across. The leaflets are attached to the midrib by their whole base, and where they unite with it are nearly in contact one with another, but not confluent. They are about one tenth of an inch wide, preserve a nearly uniform breadth from the base outward, and are *bluntly* rounded off at the extremity. They are from one to two inches long, becoming shorter towards the upper end of the leaf, and are either straight or slightly falcated. From the lower end of the leaf to near the upper, the pinnules are placed at an angle of from seventy to eighty degrees with the midrib; at the upper end they make a more acute angle. Each pinnule is marked by from three to six parallel veins, springing from the midrib, and running to the extremity. As yet I have met with no specimen exhibiting the stem and pinnæ in connection, and I am therefore unable to speak of the character of the stem to which these leaves belong.

On comparing this fossil with the figures given by Professor Phillips, and by Lindley and Hutton, of the several species of *Cycadites* or *Pterophyllum*, found in the *Öolite* rocks of Yorkshire, &c., it will be found, along with a marked general resemblance, to present several striking peculiarities. Nor does it bear even as near a specific analogy to the other fossils of the same tribe, figured and described by Sternberg.

The fossil which it most closely resembles is one which I find figured among the illustrations of Captain Grant's interesting 'Memoir on the Geology of Cutch,' (Geol. Trans., vol. 5,) under the title of "*Ptilophyllum acutifolium.*" In the latter, however, the leaflets have an "acute apex," and are "imbricated at the base, and attached obliquely," in all of which characters it differs from the Virginia fossil.

In accordance with the generic characters which appear to have guided Prof. Phillips, this fossil would rank as a *Cycadites*, while in obedience to the definition of Brongniart, and Lindley and Hutton, it should be placed in the genus *Pterophyllum*. Preferring what appears to me the simpler arrangement of the *Cycadites* adopted by Sternberg and Presl, I have rather chosen to place it in the comprehensive genus *Zamites* of the latter author, adding the specific name *obtusifolius*, as descriptive of the mode of termination of the leaflets. The propriety of referring it to this genus will at once appear on comparing the above description of the fossil and the accompanying figure, with that part of Sternberg's definition of the genus which relates to the leaves, comprised in the following words:

" *Folia pinnatifida, vel pinnata, pinnis distichis, sessilibus adnatisve, laciniisque integerrimis nervosis, nervi plures, paralleli, in basi pinnarum vel laciniarum juxta depositi.*"

It will be seen that the *Zamites obtusifolius*, as above characterized, bears a close resemblance, in most particulars, to the fossil figured and described by Brongniart, under the title of *Filicites vittarioides*, and since described by Sternberg as *Zamites blechnoides.* Vide Hist. des Veg. Fos: Liv. 11, p. 391, and Sternberg's Versuch, &c., part 7 and 8, p. 200. Though this fossil is spoken of by Brongniart as having been sent to him by Prof. Silliman, from the coal-field of Eastern Virginia, I have been unable to find it anywhere in this region. The points in which, according to the description of Brongniart it differs from *Z. obtusifolius*, are the confluent form of the pinnules where they join the midrib, and the invariable presence of but *two nerves* in each pinnule.

Zamites tenuistriatus.

The impressions of this fossil, which I have thus far met with, are imperfect and rather obscure, consisting of disjoined leaflets and incomplete fronds. They are, however, sufficiently distinct to show the peculiar form of the leaflets, their mode of attachment to the midrib, and their nervation.

The leaflets, varying from three fourths of an inch to one inch in length, and from one eighth to one tenth of an inch in breadth, where widest, are sharply elliptical at base, attached directly to the midrib, and taper with great regularity from the place of greatest width (about one fourth the whole length from the midrib) to their termination. The nervures are parallel, numerous, and so delicate as to be but obscurely traceable on most of the impressions.

The fossil to which this appears to bear most analogy, is the *Zamites Whitbiensis* of Sternberg; but the leaflets of the Virginia plant are much smaller, more delicate, and of a narrower form, and the nervures much more minute.

Zamites.

One of the most abundant of all the fossil relics found in the dark-colored slates a short distance above the coal, and sometimes interlaminated with the upper part of the seam, consists of long flat impressions, covered with straight parallel ribs or veins from thirty to forty to the inch. These impressions lie closely upon each other, between the parallel laminæ of the slate, and appear to be of extreme thinness. The great distance to which the parallel ribs may be traced, without any indications of an articulation, and the close proximity of the impressions, would seem to exclude the supposition of their being compressed stems of a *Calamite*, while their narrowness and nearly uniform width, and some obscure appearances of attachment to a midrib, incline me to refer them to some very large *Cycadeous* plant.

The above-described fossils comprise the more important, though not all of the vegetable remains which I have yet been able to procure in a state of sufficient preservation to be of much interest for purposes of comparison. Further explorations in which I am now engaged, will, it is hoped, add many new ones to the list, and enable me clearly to determine the characters of a number of interesting, but as yet obscure plants, of which I now have specimens.

Of animal remains, the only specimens, thus far met with, are a single species of *fish*, and the *teeth* of what was probably a *Saurian*. The former, which has been accurately described by Mr. Redfield, is referred by him to his new genus *Catopterus*, under the title of *Catopterus macrurus*.* Its remains are met with profusely, though seldom in good preservation, in the black bituminous slates and lead-colored argillaceous sandstones, im-

* See American Journal of Science, for 1841, vol. 41. p. 27.

mediately upon, and for some distance above, the coal. In some localities the rhombic scales occur in immense numbers, blended with vegetable impressions, not only in these beds, but in the upper part of the coal itself. The teeth I have found both in the finer grits, and associated with the fish scales immediately upon, and in, the coal.

Description of the Tin Veins of Jackson, N. H. By Charles T. Jackson, M. D., *State Geologist.*

A few minute and scattered crystals of oxide of tin had been noticed in the albite rock of Chesterfield,* and in a block of granite at Goshen,† anterior to the discovery of the tin veins of New Hampshire, which are to be described in the present memoir. We have been informed by Prof. W. B. Rogers, at this meeting, that a few scattered crystals of this ore were observed in the auriferous veins of Virginia. No regular veins of the tin ore have been found at any of the above-mentioned localities. I have the satisfaction of announcing to the Association, that in 1840 I discovered several regular veins of the oxide of tin in the town of Jackson, N. H., on the estate of Mr. William Eastman. I have laid before you specimens of the ore, and an ingot of the metal extracted from it. Also, specimens of the accompanying or associated minerals which occur in the tin veins.

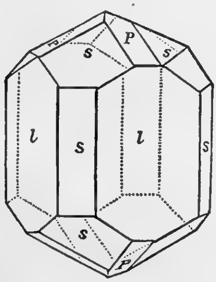
The locality where these ores are found, is situated on a hill a little to the eastward of the White Mountains. The rocks which compose the mass of the hill are mica slate, gneiss, and granite, with occasional dykes of compact and porphyritic greenstone trap. The stratified rocks run in a northwest by west and southeast by south direction, and dip to the northeast by east thirty degrees.

* See Haidinger's Translation of Mohs' Mineralogy, Vol. II, p. 387, Edinburgh, 1825.

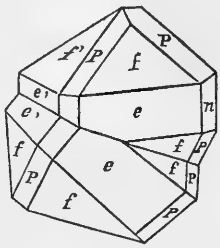
† See Prof. Hitchcock's Report on the Geology of Massachusetts, page 74.

Across the strata at acute angles, veins of granite intersect the mica slate, and run north and south. The granite veins and the mica slate and gneiss rocks are intersected by trap dykes running northeast and southwest.

Included in the granite veins, and passing into the mica slate, occurs a vein of arsenical iron, or arsenical pyrites, which runs north forty degrees east, south forty degrees west, and is from one to four inches in width, and at least three hundred and twenty-eight feet in length. This vein is cut off by the trap dyke, and it was at the junction of this dyke with the vein that I first noticed the occurrence of crystals of the oxide of tin, associated with copper pyrites, the ore being abundantly mixed throughout the vein stone, which is a deep chocolate-brown mica slate, deeply colored by tungstate of manganese and iron. The oxide of tin in that part of the vein is highly crystalline; and distinct crystals, generally as large as a grain of wheat, are thickly implanted in it, and may be picked or washed out for examination. The largest which were obtained are one quarter of an inch in length, and their forms either that of the right square prism, modified by numerous facets, or modifications of the primary octahedron, with a square base, as represented in Mohs' Mineralogy, Vol. II, plate XIX, fig. 102. See p. 81. Hemitropic crystals also abound, having the form as represented in fig. 2.



1.



2.

The color of the crystallized oxide of tin is of a deep hair brown; rarely, it is almost black. The small crystals are translucent, and are, when viewed by transmitted light, of a yellowish brown color. Their lustre, when free from striæ, is adamantine. They are sufficiently hard to scratch phosphate of lime, but not quite so hard as adularia. Specific gravity of the compact ore, containing a few particles of quartz, 6.458 to 6.487. The compact ore is found investing the walls of the veins, and the smallest ones have a thin layer of quartz running through the centre, in which are implanted numerous brilliant crystals of the oxide of tin, which are remarkably perfect. Before the blowpipe alone, this ore is infusible; nor does it dissolve in glass of borax, or in biphosphate of soda. It is insoluble in acids. Pulverized and mixed with powdered charcoal, with two thirds carbonate of soda and one third glass of borax, it is readily reduced on charcoal to metallic tin, which may be thus separated in brilliant globules, or in a small button.

These globules, when acted upon by nitric acid, are converted into insoluble stannic acid, which is of a white color, and is also insoluble in acids. It was evident, when a fragment of the tin ore was reduced to the metallic state, that the metal was nearly equal to three fourths of the bulk of the ore reduced.

On pulverizing and washing a quantity of the vein stone containing crystals and grains of the oxide of tin, a heavy ore was obtained, containing a few particles of the arsenical pyrites and a little copper ore, which, on being roasted, to free it from arsenic, and reduced, yielded, according to the purity of the specimen, from thirty to fifty per cent. of tin. A selected specimen of the compact oxide, reduced to the metallic state, yielded seventy-three per cent. of tin, which was perfectly pure.

An average lot of the fragments of ore taken from the small veins, when reduced, yielded sixty-four per cent. of metal, which was impure, but on being refined gave fifty-four per cent. of pure tin.

Five ounces of the pulverized ore was taken for reduction. It was first boiled with a little nitric acid, to remove the soluble oxides and impurities, and then reduced in a crucible lined with lampblack, at a forge heat, and yielded three ounces of pure tin, which was cast into an ingot. This is the specimen now laid before the Association. A piece of the ingot was cut off and rolled out into a sheet, which was also exhibited. This specimen is, in fact, the first ingot of tin that has been extracted from an ore found in this country.

Since the discovery of the largest tin vein in Jackson, three others of smaller dimensions have been found, which yield a perfectly compact and nearly pure oxide of tin. One of them widens as it descends in the rock.

Minerals found associated with the Tin Ore of Jackson, N. H.

Oxide of tin in crystals and in compact veins of tin-stone, arsenical iron, and arseniate of iron, are abundant. Copper pyrites or bi-sulphuret of copper and iron, in disseminated masses. Native copper, in thin folia, rare; oxide of iron, not abundant, but mixed with the mica slate of the vein; iron pyrites, in crystals, abundant, disseminated. Wolfram disseminated in the veinstone not crystallized; fluor spar, investing the walls of the veins, color light pink, or white and transparent; mica, brown-colored, in fine scales; black tourmaline, radiated in small crystals in the granite; phosphate of lime rare, yellowish-colored crystals; quartz in crystals and crystalline grains; it occurs also in thin layers, forming the middle seams in the small veins, serving as a separation of the investing coats of compact tin ore on the sides of the veins, the deposit of tin ore having been made on the walls of the fissure.

It will be perceived, that the above-mentioned minerals are those which generally occur in the principal tin mines of Cornwall, Bohemia, and Saxony; and hence we may infer, that the circumstances under which the ores in these different regions were deposited, were similar, if not identical. It gives us reason to believe, that the New Hampshire tin mines may prove valuable. The largest part of the vein was eight inches wide, and it contracted to the southward to a vein one inch in width. The small veins run east and west, or across the strata, and they are from one fourth of an inch to one inch wide; but are much richer than those of larger dimensions. The ore is generally pure compact oxide of tin. It is probable, that, in working the mine, numerous dilatations of the metalliferous lode will occur, forming stockwerkes and pockets of tin-stone. As yet, no excavations have been made to a greater depth than three feet; and hence we are unable to estimate the probable value of the ore which may be obtained by mining. Tracing the principal vein to the southward, we lost sight of it in the valley; but on the rising ground beyond we again found the ore, with its usual associated minerals. This locality is one fourth of a mile south of the principal vein, and in the direction of its course.

On revisiting this locality, I discovered several new veins of compact oxide of tin, and obtained ninety-eight pounds of the ore, which yields on the average forty per cent. of tin, while the clean ore freed from the rock yields seventy-three per cent. of metal. By a single assay of this ore I obtained from twenty-one ounces of rock and ore, taken just as it was blasted out, eleven and a half ounces of pure tin.

Remarks on the Theory of the formation of Tin Veins.

M. Daubrée, Ingéneur des Mines, has published some interesting remarks on the theory of tin veins. (Annales des Mines, tome XX, 4me livraison July and August, 1841.)

He considers the origin of the oxide of tin in veins to have arisen from the volatilization by heat of the fluoride of tin from the interior of the globe; and that, as the fluoride, thus sublimed into crevices of the rocks, was decomposed by water or earthy bases, the oxide of tin was deposited on the surfaces of the fissures, and the veins became filled with the ore.

In order to prove the presence of fluorine, he cites the fact of the constant occurrence of fluor spar in tin mines, and also regards the investing layers and crystals of quartz as formed by the sublimation of fluorides. He also supposes, that the combinations of boron and fluorine were raised in vapor, and that the occurrence of tourmaline in all tin veins is a proof that boron was present at the time of their formation, that mineral containing boracic acid. Mica also, containing fluoric acid, is a frequent associated mineral in tin veins.

It is interesting to observe the remarkable agreement of the facts noticed at Jackson with those cited by M. Daubrée. It is evident, at our locality, that the oxide of tin was deposited in layers on the sides of the fissured rocks, and that the veins were thus filled up with the oxide by deposition from the sides to the middle.

This author refers to the sublimation of chloride of iron in the crater of Vesuvius as presenting analogous phenomena. There, as originally observed by M. Gay Lussac, the specular oxide of iron which invests the fissures in the lava, and lines the walls of the caverns, is produced by the sublimation of chloride of iron, which is decomposed by the agency of steam, chlor-hydric acid being formed, and peroxide of iron deposited.

Remarks on Zinc, Lead, and Copper Ores of New Hampshire. By C. T. Jackson.

It is surprising that the rich veins of blende or sulphuret of zinc, which occur so abundantly in this country should be wholly neglected, when it is so easy to extract the metal from the ore. By roasting the sulphuret of zinc at a dull red heat in a reverberatory furnace, it is readily converted into the oxide of zinc, which, being mixed with charcoal and distilled, will yield forty per cent. of the metal. A remarkably pure yellow blende occurs in the town of Eaton, N. H.; and several hundred tons of that ore have been raised during the working of the mine for lead, and it still remains around the mouth of the mine neglected.

Black blende also occurs in large veins in the town of Warren, N. H., and smaller ones are found at the lead mines of Shelburne, and in Lyman.

Assays of Blende.

Two thousand grains of the Eaton blende having been roasted, and thus converted into oxide of zinc, yielded on distillation seven hundred and seventy-seven grains of pure zinc, or 38.8 per cent. About two per cent. of the zinc was lost by adhesion to the neck of the retort, and we may reckon the yield of the ore in the large way at forty per cent.

Two thousand grains of the black blende of Warren yielded by the same operations four hundred grains of pure distilled zinc, or twenty per cent. In the large way it would give from twenty-five to thirty per cent. of the metal.

I exhibited to the Association specimens of the ores here mentioned, with the metals extracted from them.

Assay of the Galena of Shelburne, N. H.

Two thousand grains of the galena yielded fifteen hundred and fifty-eight grains of lead, or 77.8 per cent. The lead cupelled gave 2.5 grains of pure silver, or two and a half pounds to the ton of ore.

The galena of Eaton also contains sufficient proportion of silver to repay the expense of extracting it from the lead. It contains eighty-four per cent. of lead, and a ton of the lead will yield two pounds of silver.

Provided the zinc and lead ores are both wrought, it might prove profitable to renew operations at these mines.

At Warren, copper pyrites of great purity occurs, associated with tremolite rock, the ore yielding, when pure, thirty-two per cent. of copper, by assay. If the copper ores are wrought, it will be easy to manufacture brass from this copper, and the oxide of zinc prepared from the blende occurring near the copper vein. Researches are now going on to ascertain whether the copper vein becomes richer and more solid as it descends into the rock.

On the Connection of Thermal Springs in Virginia, with Anticlinal Axes and Faults. By William B. Rogers, *Professor of Natural Philosophy in the University of Virginia.*

The proximity of some of the noted Thermal Springs of Europe to lines of remarkable disturbance in the stratification, appears to have been early noticed. Whitehurst long ago, in his Theory of the Earth, alluded to this peculiarity of geological position, when speaking of the waters of Matlock. In recent times similar observations have been greatly multiplied. Stifft has made particular mention of saddle-shaped elevations of the strata, often accompanied by fractures, as marking the position of the thermals of Nassau. Hoffman has described the waters of Pyrmont, as flowing out in a valley of elevation of a nearly circular form. Conybeare and Buckland have called attention to the remarkable dislocation in the neighborhood of the Bristol hot wells, and Lyell and Murchison have noticed similar phenomena in the vicinity of Aix, in Provence; while Forbes has made known the important fact, that a large class of thermals in the Pyrenees, and probably elsewhere, flow out at the common boundary of the hypogene and stratified rocks.

Further instances of the association of thermal springs with dislocations of the strata, and other marks of uplifting and intrusive action, are mentioned by Dr. Gardner in his valuable treatise on mineral and thermal springs, and still more lately by Dr. Daubeny, in his lucid and comprehensive report on the same subject to the British Association. To the latter distinguished geologist we are indebted for many interesting speculations founded on these and other peculiarities of thermal springs, viewed in their connection with the theory of volcanic agency, of which he has long been the ingenious and zealous advocate; and to Professor Bischoff, of Bonn, we are under equal obligations for an elaborate and masterly analysis of the mechanical, geological, and chemical conditions connected with the flow of such waters, together with an explanation of their temperature and impregnation, deduced from the theory of a general subterranean heat.

With the exception of brief and rather incidental notices published by myself and others, and the communications of Dr. Daubeny to Silliman's Journal and the Ashmolean Society, no account has yet been given of the peculiarities of geological structure, associated with the thermal springs of the United States. Indeed, the supposed rareness of their occurrence in this country, compared with many parts of Europe, and their comparatively slight excess of temperature in most instances over the ordinary springs, have naturally rendered them less inviting as subjects of observation. It is hoped, however, that the details about to be presented, by proving their frequency in a part of the Appalachian chain, in which until of late years only a few were believed to exist, will encourage a search for them in other parts of this extended mountain belt.

My objects in the present communication are *first*, to call attention to the very *frequent* occurrence of thermal springs among the axes of the Appalachian chain in Virginia; *secondly*, to indicate certain *laws of position*, by which I have found them to be governed, and *thirdly*, to point out the important bearings of those facts when connected with the peculiar geology of the region, upon the theory of a generally diffused internal heat.

According to the views of Professors Daubeny and Bischoff, every spring is to be regarded as *Thermal*, whose temperature exceeds the atmospheric mean of the region in which it is situated: and in conformity with this definition, the former of these philosophers has proposed, "in constructing a scale of temperature in regard to them, to calculate it not by their actual warmth, but by the degree of their excess above the mean of the climate." The propriety of this suggestion, which he has himself carried into execution in the very valuable Table appended to his 'Report on Mineral and Thermal Waters,' is obvious upon a moment's consideration. Thus we know, that the ordinary superficial springs under the equator have a temperature as high as some of the celebrated thermal waters of Europe and America. In Mexico the temperature of seventy-two degrees, corresponding with the mean of the climate, belongs to the common springs, while in Virginia the same temperature renders decidedly thermal the well-known fountains of the Sweet Spring Valley, which rise in a region whose average is about fifty-one degrees.

Admitting that the elevated temperature, observed in mines and Artesian wells, is dependent upon a generally diffused internal heat, increasing with the depth, and not upon chemical or volcanic agencies of local operation, the class of thermal waters, as above described, ought to include a large proportion of such springs as are not of superficial origin. Indeed, under any view of the sources of their temperature, all springs ought to be included in this class whose heat is invariable, or when liable to change never sinks below the atmospheric mean of the place.* Some decidedly thermal springs, as, for example, the White Sulphur Springs of Virginia, display considerable variations of temperature with the change of seasons or of weather. It would, therefore, not be correct to assume *permanency* of heat as the criterion of thermal character, however completely, in the ordinary circumstances of springs, such permanency would seem to prove that the waters in which it is observed belong to the thermal class. It may be fairly assumed in general, that a spring presenting a uniform temperature, or one which, in its fluctuations, never descends below the atmospheric mean, cannot be dependent for its heat upon the atmosphere and superficial strata. Hence the general dissemination of such springs over a widely extended region, *furnishes the strongest evidence for the existence of a perennial source of heat within the earth.*

As remarked by Bischoff, the coldest springs of uniform temperature, provided they do not derive their waters from a neighboring mountain, will exhibit the nearest approximation to the average temperature of the country; but will always be a little, though it may be a very little higher. Guided by these views, he has shown, from extensive observations in Germany and other parts of Europe, that thermal springs are of far more frequent occurrence than had been supposed, and, indeed, that nearly all the copious mineral springs there, and probably, by inference, in

* Of course, this is intended to include springs originating in glaciers or near the tops of high mountains.

other parts of the Continent, are of this denomination. Out of *twenty* mineral springs in the vicinity of the Lacher See, which he continued to observe at different seasons for several years, the coldest always exceeded the mean of the place by about two degrees and twenty-five minutes, thus proving them all to be unquestionably thermal. Similar observations on the springs of the Dippe, Jordan, Pader, and Heder, flowing from the foot of the chalk rocks of the Teutoburges-wald, brought to light the fact, that out of *sixty-six* running fresh-water springs, only three had a temperature below forty-seven degrees seventy-five minutes, the mean of the place, making *sixty-three* to belong to the thermal class. In like manner Prof. Forbes found the temperature of a number of copious springs upon the Rhine, not before supposed to be thermal, to exceed by several degrees the mean of the place.

Observations of these *slightly thermal*, as well as of warmer springs, though thus numerous in some parts of Europe, have perhaps been too much confined to such regions as are known or may be supposed to have been at one time the theatre of *local volcanic activity*, to admit of our inferring, with confidence, that the elevation of temperature thus observed, is the result of a generally pervasive heat within the earth. Indeed, the very frequent occurrence of intrusive igneous masses, among the rocks of a large part of Europe, is calculated to weaken the force of such an inference generally, as applied to that portion of the earth's crust.

In this country, the vast belt of mountains occupied by the Appalachian strata, presents, as I conceive, a region peculiarly favorable for *unambiguous* observations of this class, in consequence of the absence, excepting along its eastern border, of trappean or other erupted rocks. It is therefore greatly to be regretted, that so little has been done towards an accurate determination of the temperature of the perennial springs of this region, more particularly of such as are situated near conspicuous axes and lines of fault. From my own observations made from time to time during the last eight years, chiefly in Virginia, I am led to conclude that a great proportion of the copious and constant springs of this belt, and more especially those of our great limestone valley, are truly though slightly thermal, and that they owe to a deep subterranean source the remarkable uniformity of temperature they exhibit. As, however, accurate determinations of the atmospheric mean, as well as minute observations on the springs at various seasons, are requisite in deciding with certainty upon their thermal character, and as we are yet very imperfectly provided with these data, the question, with regard to a great number of our bold springs, must still remain unsettled. I therefore restrict myself in the present paper to a notice of such as are decidedly and unequivocally thermal.

The following Tables comprise all the well-marked thermal springs of Virginia, either previously known, or which have been brought to light by myself and my assistants, in the survey of the State.

Table I, relating principally to the thermals which are best known and most resorted to by invalids, includes, in regard to most of them, a statement of the names and relative quantities of the evolved gases, with the names of the gaseous and principal solid ingredients.

In Table II, these particulars are omitted, as being of less present interest with regard to most of the springs it embraces, but occasional notices are annexed of the evolved gases and of the contents of the waters. I may add, that a minute account of the ingredients of our thermal and mineral springs generally, derived from a long series of analyses in which I have been engaged for many years, will be made public in another form. It will be seen, that some of the springs, embraced in Table II, have a temperature but little above the atmospheric mean, yet their thermal character is believed to have been fully established by the permanency of this excess.

CATALOGUE OF THE THERMAL

Table I.

	Name of Spring.	Geographical Position.	Geological Position.
	Warm Springs,	W'm Spring Valley, Bath County,	In anticlinal axis of Formation II, of Va. and Pa. Reports,
1	1. Principal Bath,		
2	2. Drinking Spring,		
	Hot Springs,	Same Valley as above, in Bath County,	In same axis as above,
3	1. Gentleman's Boiler,		
4	2. Spout Bath,		
5	3. Red Spring,		
6	4. Pleasure Bath,		
7	5. Barrel Spring,		
8	6. Sweet Spring,		
9	7. Gent's Lower Spout,		
10	8. Ladies' Hot Spout,		
11	*Gap Spring,*	N. W. of W'm Spring on road to Bull Pasture,	In the above axis near N.W. termina. of expos. For. II.
	Sweet Alum Springs,	3 miles S. W. Hot Springs,	In the above axis, For. II.
12	1. Toothache Spring,		
13	2. Healing Spring,		
14	3. Spring near Road,		
15	*Falling Spring,*	Near Covington,	Near S. W. end of same axis, For. II.
	Sweet Springs,	Sweet Spring Valley, Allegheny County,	Anticlinal axis passing into fault. N. W. side of II.
16	1. Drinking Spr. near Hotel,		
17	2. Old Red Spring,		
18	3. Rogers' Red Spring, or Champaigne Spring,		
19	4. Bubbling Fountain,		
20	5. Western Spring,		
	Snake Run Springs,	Near N. E. end Sw. Spring Valley,	In same axis, termination of For. II.
21	1. Two large Springs,		
22	2. Less, but Cold Springs,		
	Bath Springs,	Warm Spring Ridge, Bath, Morgan County,	S. E. flank of anticl. axis of Capon Mt. in For. VII.
23	1. Spring near Hotel,		
24	2. Southwest of (1)		
25	3 Southwest of (2)		
26	*White Sulphur,*	Greenbrier County,	In anticl. axis of For. VII.
27	*Wilson's Thermal,*	Near Long's Entry Creek, Botetourt County,	In anticl. of For. VII. N.W. of axis of Biggs's Mt.
28	*McHenry's Spring,*	Near N. Fork of Holston River, Scott County,	Near fault bringing For. II. in con. with For. XI, in XI.

SPRINGS OF VIRGINIA.

TABLE I—CONTINUED.

	Temp. of spring.	Temp. of place.	Gases evolved.				Gaseous Ingredients. 100 cubic inches contain				Princi. solid ingredients. Total 100 in cubic inches.
			Nit.	Ox.	C. ac.	S.Hyd.	Nit.	Ox.	C. ac.	S.Hyd.	
1	$97\frac{1}{2}°$	51°	98.	2.6	$\frac{3}{4}$	$\frac{1}{4}$	1.62	trace	2.64	0.21	1 { 10.64 grs. consist. of Sul. Lime, S. Mag. S. Soda. Carb. Lime.
2	96	"	"	"	"	"	"	"	"	"	2. C. Magnesia, &c.
3	106	"	84.8	5.	10.2	"	1.79	0.32	11.	trace	3 { 13.25 grs. do. with a decided amount of carbonate of iron.
4	108	"	....	....	......	......	1.77	0.28	11.8	......	
5	105	"	84.	0	14.	"	1.50	0.24	11.6	......	
6	102	"	87.5	0	12.5	......	....	....	......	......	4. 12.73 grs. same.
7	$102\frac{1}{2}$	"	75.	6.	19	......	1.80	0.2	11.5	......	5. 15.61 grs. same.
8	93	"	....	....	......	......	2.10	0.35	11.7	......	7. 13.12 grs. same.
9	103	......	....	....	......	......	....	....	......	......	8. 14.5 grs. same.
10	......	......	....	....	......	......	....	....	......	......	9. 42.75 grs. same.
11	71	"	....	....	......	......	....	....	......	......	10. 13.8 grs. same.
											Chlorides of Sodium, Calcium & Mag. exist in
12	85										all these waters in small amount; also very faint
13	83										traces of Iodine. The
14	74										same is true of those
15	62	"									which follow as far as 26.
16	74	......	71.7	....	28.3	......	1.87	trace	31.87	trace	16 { 32.67 grs. main ingredient same as above.
17	75	......	77.3	....	22.7	......	2.12	"	35.6	......	17 { 33.84 grs. same, with more Carb. Iron.
18	{ 76 / 78	......	62.5	....	37.5	......	2.57	0.20	46.1	......	18 { 40.76 grs. same, with more Carb. Iron.
19	74	......	82.	5.	13						
20	72	......	77.2	....	22.8	......	1.6	trace	30.55	......	20. 41.21 grs. same.
											23, 24, 25 { 4.75 grs. chiefly Carb. Lime, and Mag. and Sulph. of same basis.
21	72										26. 65.54 grs. Carb. Lime
22	67										and Mag., Sulph. Lime, Mag. & Soda, chloride of Sodium, Magn. and Cal-
23	73	52?	89.7	9 2	1.1	......	1.32	0.12	1.14	......	cium, Sul. Hyd. of Mag-
24	74	"	"	"	"	......	"	"	"	......	nesium, &c. Sulph. Iron,
25	72.5	"	"	"	"	......	"	"	"	......	a marked amount of Io-
26	61 to 65	......	....	....	......	......	1 78	0.19	2.07	......	dine, Sulphur blended with organic matter.
27	65	"	....	....	......	......	....	....	......	......	27 { 22.85 grs. same as 1, 2, &c.
28	68	53?	....	....	......	......	....	....	......	......	28. 26.04 grs. same.

Table II.

	Temp. of Spring.	Temp. of place.	Name of Spring.	Geographical Position.	Geological Position.
			Bon Springs.	Cedar creek valley, Shenandoah co.	In steep anticlinal axis of For. VI. Springs bold and constant; some gas — Nit. and C. acid. ....
29	57.	52?	1. Enclosed Spring,		
30	56.		2. Open Spring,		
31	55.75		3. Open Spring,		
			Capon, or Cacapon,	Near Watson town, Hampshire co.	N. W. side of anticl. axis of Paddy Mt. from vert. strata of For. VII. Copious and constant.
32	61.	......	1. Principal Spring,		
33	57.		2. Sp. higher up Mt.		
34	55.		3. Sp. " than (2)		
35	51.		4. Sp. " than (3)		
			Keyser's Thermal,	Near Clifton forge, on Jackson river, Rockbridge co.	S. E. side of anticl. of Red Patch Mt. From For. VI. Copious and constant. Some gas — Nit. Carb. acid and Ox.
36	64.	......	1. Large Spring.		
37	61.		2. Five smaller Sp.		
38	62.	......	*Mill Mt. Spring,*	Panther gap, Mill Mt., Rockbridge co.	S. E. side of anticl. of Mill Mt. From For. VI. Copious and constant.
39	56.	......	*Haycock's Spring,* ...	N. W. side of Big Sandy ridge, Hardy county.	Anticlinal axis of North river Mt. from For. VI. Very bold and constant.
40	60. 61.6	..	*Pearce's Springs,*	Near Pearce's furnace, N. W. side of Paddy's Mt.	N. W. side of anticl. of Paddy's cove. Junction of For. VI. and VII.
41	55.	......	*Spr'gs near Wardensville,*	Hardy county.	N. W. side of anticl. of Chestnut Ridge, from For. VII.
42	56.	......	*Busby's Spring,*	W. of Wardensville, Hardy co.	N. W. side of anticl. of Big Sandy. From junc. of For VII. and VIII.
43	61.5	... 51. 52?	*Nap's Creek Spring,* .	Near Huntersville, Pocahontas county.	Anticl. axis of Brown's Mt. For. VI. Much gas. Nit. C. acid.
			Walker's valley Sp.	Valley of Walker's Creek, Wythe co.	Axis in For. II. Rocks nearly vertical. Bold. Gas
44	57.5	......	1. Largest Spring, .		
			2. Less Springs, ..	....	No gas.
45	56.		*Sp. near Galbraith's,*	....	Steep beds of For. II. Near fault of Draper's valley. Very bold sp'gs. Gas.
			1. Lower Spring, ..	South of Draper's valley, Wythe co.	
46	56.	......	2. Upper Spring, ...		
47	56.				
48	60.	......	Spr. A great group of Thermals, covering nearly half an acre, ..	On Hunting Camp Creek, near junc. with Wolf cr., Giles' co.	Near N.E. end of great Anticl. of Burk's Gard. From For. VII.
49	60.	......	*Kimberling Spring,* ..	Kimberling fork, Giles' co.	Anticl. of Little Flat top Mt. For VI.
50	56.	......	*Edmonson's Big Sp.* .	Near Roanoke river, Floyd co.	Fault; in F. II. Copious. Much gas. Nit. &c.
51	57.	......	*Limestone Spring,* ...	Near E. base of Little North Mt., Shenandoah county.	Inversion of For. II. on III. with fault. Flows from II. Bold. No gas.
52	66.	......	*Limestone Spring,* ...	Near Milford, Page county.	Inverted axis of For. II. Very copious.
53	70.	.....	*Strecklar's Spring,* ..	Entrance of Streck's Gap, Rockbridge co.	Inversion of For. II. on III. with fault. Flows from II. Bold. Nit. Ox. and C. acid.
		......	*Buford's gap Springs,*	S. E. of Blue ridge, at Buford's Gap, Bedford co.	Junction of For. I. with Hypogene rocks.
54	66.		1st Spring,		
55	72.		2d Spring,		
56	75.		3d Spring,		

The details embraced in the preceding tables of our thermal springs, will, I think, justify the assertion, that in no region hitherto described is the connection of springs of this class with the structural features of the district in which they occur, so uniformly and extensively displayed as in our Appalachian belt. The *fifty-six* springs here enumerated embrace *twenty-five* distinct lines and individual localities, situated in various and remote parts of the valley, and the mountainous belt adjoining it on the northwest, making in all an area of about fifteen thousand square miles. *Forty-six* of these springs are situated on or adjacent to anticlinal axes, *seven* on or near lines of fault and inversion, and *three*, the only group of this kind yet known in Virginia, close to the point of junction of the Appalachian with the Hypogene rocks.

It may therefore be announced as the prevailing *law*, as regards the more decided thermals of Virginia, and I have reason to believe of other parts of the Appalachian belt, that *they issue from the lines of anticlinal axes, or from points very near such lines.*

A glance at the several short sections accompanying this paper, aided by the following brief comments, will serve more particularly to illustrate the conditions under which they thus generally occur, and to impart just conceptions of the structure of the districts in which they are situated.* (Plate XVI.)

SECTION I. *From the Warm Springs to the Little North Mountain.*

SECTION II. *Passing through the Hot Springs.*

SECTION III. *Passing through the Gap Spring and Ebbing Spring.*

SECTION IV. *Through axis at Keyser's Springs.*

In the first of these Sections are embraced three thermal localities, presenting distinct geological conditions. In the most western, that of the well-known Warm Springs, the water comes to the surface in the line of an anticlinal axis. In the next, that at the Mill Mountain, it flows out on the southeastern side of the

* The scale of the Sections is two and a half miles to the inch, or twice that of the large State map. The eastern part of Section VIII is, by mistake, too much expanded.

axis, and in the third it issues from rocks, presenting a great inversion, accompanied by a fault.

The *Warm Springs* rise to the surface through fissures, in a massive bluish limestone, a part of Formation II, of the Virginia and Pennsylvania Reports, and corresponding to the Black river limestone of the New York geologists. This rock forms the surface of a long and narrow anticlinal valley, extending from beyond the Gap Spring (Section III) to the neighborhood of the Falling Spring, (Table I, No. 15,) a distance of about thirty miles, nearly in a direction from northeast to southwest. Beyond this, towards the northeast, the higher formations close over the limestone, forming a lofty unbroken mountain, in the prolongation of which the axis gradually dies out. A similar though more rapid change terminates the axis at the southwest, its entire length being about sixty miles.

The rocks on the northwest side of this axis, forming the Little Warm Spring mountain, are in general either vertical, or overturned, while those on the southeast, constituting the lofty and massive range of the Warm Spring mountain proper, present a moderate southeastern dip, excepting at a few points where the inclination for a short distance is much steeper.* The line of thermals situated in this axis, includes those of Table I, from 1 to 15, inclusive. Of these, the least thermal, the Gap Spring and Falling Spring, are found towards the extremities of the anticlinal valley; those nearer the centre of its length, the Warm Springs and Sweet Alum Springs, have a much higher temperature, and the Hot Springs, occupying a central position, are the warmest of all. At the latter point, the flexure of the strata appears to have attained its maximum, and is of the *folded* kind, the rocks of the northwest side of the valley, and of the Little Warm Spring mountain, being inverted for a thickness of about three thousand feet.

The amount of water issuing from these springs is so great as to form the chief part of the Warm Spring creek, Cedar creek, and other streams flowing out of the valley towards the north-

* This unusually steep inclination on the southeast side of the axis, is seen opposite the Warm Springs on the main road.

west. At all these points much gaseous matter is evolved along with the water, consisting in great part of nitrogen, with some carbonic acid, a very little and in certain cases no oxygen, and at two or three points a slight admixture of sulphureted hydrogen.

The position of this valley between two lofty ridges, which uniting at its opposite extremes form a complete enclosure around it, and the steep inclination of the strata along the western part of its surface, are just such conditions as might be expected to give rise to a large accumulation of water at great depth, and to furnish a hydrostatic force capable of raising it to the surface. It appears to me, therefore, that in speculating upon the mechanical agencies concerned in the emissions of these thermals, we are not called upon to imagine any other force than that of the simple pressure of aqueous columns, either continuous or interrupted by gases accumulated in the same fissures or cavities within the earth. Nor, in tracing to their origin the temperature, evolved gases, and the chemical ingredients of these waters, do I conceive that any further conditions are required, than the access of the air and meteoric waters to rocky masses at a great depth below the surface, and whose temperature, due to that depth, sustains the chemical actions necessary to give the proper impregnation to the springs.

In glancing the eye along Section I, it will be seen that the flexures of the strata are such as to give the axis-planes an *oblique* position, dipping towards the southeast; a structure equally distinct also in the other sections, and which is in conformity with a *general law*, already announced by my brother, Prof. H. D. Rogers and myself, in a joint paper 'On the Structure of the Appalachian Chain,' read to the Association.* In consequence of such a flexure, the strata of the Mill Mountain, on the western side, are thrown into an inverted position; those on the east, in which the *Thermal of Panther Gap* rises, preserving a moderate dip towards the southeast. This bold spring, accompanied by a good deal of gas, chiefly nitrogen, issues from beds of limestone belonging to

* To this paper, and the accompanying Sections and Diagrams, I would refer for a full exposition of this law, and for explanations of the terms *normal and folded flexures*, *axis-plane*, &c., used in the present article.

our For. VI, nearly equivalent to the Pentamerus limestone of New York.

The same conditions accompany the group of thermals marked on Section IV. The strata here are more slightly inverted on the northwest, and their *curvature* is so well preserved, even in the massive beds of sandstone, (For. IV, Shawangunk grit of New York,) as to present, in the grand exposure at Clifton forge, a vast rocky arch of more than half a mile in span.

The thermal at the southeastern extremity of Section I, is associated with a different structure. The limestone (For. II) of the great valley is here, as in most places near the foot of the Little North Mountain, *thrown over upon For. III.* This inversion, due to a folded axis lying parallel to and southeast of that ridge, though it often extends entirely through the mountain, at this point ceases with the eastern outcrop of the lower beds of For. IV. At the junction of Formations II and III, the latter is much crushed, and a slight fault occurs. It is near this spot, in the limestone, that the warm waters make their escape. The thermal, marked at the southeastern extremity of Section X, occurs under precisely the same conditions, rising in the same rocks, thrown into the same inverted attitude.

SECTION V. *Across the Sweet Spring Valley.*

The structure of this valley, like that of the Warm Springs, is due to a great anticlinal axis. Commencing at a point southwestward of the termination of the latter, this valley extends for about fifteen miles in a nearly west-southwest direction, bounded by the Sweet Spring or Peters's Mountain on the southeast, and by the Snake Run or Little Mountain on the opposite side. Where the limestone, For. II, begins to be exposed by the opening of a great anticlinal range of For. III and IV, and for a short distance towards the southwest, the strata have a *normal flexure*, those on the northwest side of the axis dipping steeply towards the northwest. But as we proceed towards the southwest, the flexure increasing, causes an inversion of the strata on the northwest side, accompanied by an occasional crushing and partial concealment of the slate rocks of For. III. These conditions, first seen at the group of thermals on Snake Run, (Table I, Nos. 21, 22,) continue, with some fluctuations, to near the southwest end of the valley, the amount of dislocation gradually but irregularly augmenting as we trace the Little Mountain in that direction. Beyond this point the fault rapidly increases, so that in the distance of a few miles not only the rocks of the Little Mountain, but all the strata intervening between For. II, and For. XI, (carboniferous limestone) have been swallowed up. In this condition, occasionally varied by the intrusion of in-wedged knobs or masses of the ingulfed strata, we may trace this extraordinary dislocation along the northwest base of the Peters's and East River mountains for more than fifty miles, after which it is still further continued with a new topography.

The *Sweet Springs* flow out from the steep-dipping and inverted limestone near the centre of the valley; the *Red Springs* and *Snake Run group* from points nearer the junction of this rock with For. III, of the Little Mountain. The streams fed by these copious fountains, flowing towards the northwest by narrow transverse valleys through the Little and Snake Run mountains, have accumulated a great thickness of tufaceous deposit, forming in the neighborhood of the Red Springs a succession of picturesque cascades.

Gas, consisting of nitrogen with a considerable amount of carbonic acid, escapes freely from all these springs, rising from the Sweet Springs in copious streams. Much dissolved carbonic acid is also present, rendering most of these waters decidedly acidulous, and enabling them to retain in solution a marked proportion of carbonate of iron, as well as the more usual ingredients, carbonates of lime and magnesia.*

Section VI. *Through the White Sulphur Springs.*

The axis in which the White Sulphur Springs arise, and that of the thermal of Brown's Mountain, (Table II, No. 43,) are nearly though not exactly in the same line. They are further

* These are the only decidedly acidulous springs in Virginia, and I believe the only ones in the United States, excepting a few which, like Saratoga, contain also a large amount of chloride of sodium.

from the southeastern margin of the Appalachian belt than any others referred to in the tables, their distance from the Blue ridge, in a direct transverse line, being about forty miles. The White Sulphur axis, exposing For. VII, at the springs, dies out in a short distance towards the southwest; but, traced in the opposite direction, expands into a considerable ridge, bringing into view the upper part of For. VII, here of inconsiderable thickness, and eventually terminates in a roll of the slates of For. VIII, near Anthony's Creek. In the neighborhood of the springs the flexure of the strata is remarkably abrupt, the gentle slope on the southeastern, passing into a vertical or slightly inverted dip on the opposite side of the axis. With the exception of this and another adjacent but very inconsiderable line of exposures, the surface for many miles on either side is occupied by the slates and sandstones of Fors. VIII and IX, bent and contorted by numerous lesser axes, and in the Allegheny Mountain and the numerous adjoining hills, carved by denudation into a variety of picturesque forms.

The waters of the White Sulphur are copious, but accompanied by very little evolved gas. The few bubbles I have succeeded in entrapping, proved to be nearly all nitrogen, but it is uncertain whether they arose with the water from the depths below, or were developed in the basin of the spring.

Though decidedly thermal, these waters have a fluctuating temperature, never, however, as I think, approaching nearer than ten degrees to the atmospheric mean.* They form the only instance within my knowledge of a strongly sulphureous and at the same time thermal water in the United States; and in these respects bear a close analogy to certain thermals of the Pyrenees.†

* Dr. Daubeny, who visited these springs when in this country, did not advert to their being thermal. See Silliman's Journal, April, 1839.

† The *plumose, filamentous* growth, involving a large amount of hydrated sulphur, which lines the basin and outlet of these waters, and which from its color has given rise to the name of White Sulphur, is also found in other sulphureous springs in the State, and has caused the adoption of this name as descriptive of such springs as a *class*, notwithstanding their want of agreement in other and far more important particulars. Organic products of another kind, developed in the enclosures of the Red, Blue, Gray, Crimson, and Green Sulphur Springs, and whose true nature was also first suggested by myself, (see Hare's Chemistry, 1838,) have by a like connection originated the names by which these springs

SECTION VII. *Through Wilson's Thermal and across Garden Mountain.*

This section includes a partial view of the great anticlinal of the Garden Mountain, exhibiting a striking example of the folded form of flexure, with an extensive inversion on the northwest side. Behind this, towards the northwest, lies the anticlinal of Biggs's Mountain, separated from the former by an irregular trough of folded slates (For. VIII); and at the western base of Biggs's Mountain occurs the lesser axis, in which the thermal here referred to rises to the surface. While the axis of Biggs's Mountain brings up the whole thickness of For. III, *doubled upon itself*, that of Biggs's Mountain exposes no strata lower than For. V, (Medina sandstone and Clinton group of New York,) over which the beds of VI and VII are seen bending, in a rather steep normal flexure, to be again elevated in part in the low ridge of VII, (Oriskany sandstone of New York,) from which the thermal issues. The point of exit of the waters is in nearly vertical strata, a little west of the axes-plane. Beyond this, towards the northwest, is a wide expanse of For. VIII, greatly folded and contorted, in which, at no great distance from

are respectively known. Observations beyond, as well as in the State, have satisfied me, that similar organic products are to be met with, in some one or more forms, in *all the sulphureous waters* of the Appalachian belt, and that they are *peculiar* to waters of this class. Having read with great interest Dr. Lankester's "notice of the plants and animals found in the sulphureous waters in Yorkshire," as given in the Report of the British Association for 1840, I have been much gratified at finding these opinions corroborated by the observations of that gentleman in regard to the sulphureous waters of Harrowgate, Askerna, and the neighboring district, and I have enjoyed no little surprise in recognizing in the conferva which at those places "collects in large quantities around the sides of the wells," and in the animal deposit, "varying from a light pink to a rose color," the objects which impart such beauty to some of our celebrated sulphureous springs, and which six years ago I pronounced to be of "vegeto-animal" origin. I may here add, by an experiment made at that time on the water of the White Sulphur, which in its basin and outlet produces little or none of the rose-colored deposit, I found that I could at will give rise to it by collecting the liquid in an adjoining cavity in the dark sulphureous mud—and I remarked that *before* the material of the rosy film collected on the surface beneath, it continued diffused in the liquid for some time like a faint pink cloud, changing its position and its density. This, with other observations, suggested the idea of its being due to animalculæ, which under certain favorable conditions as to light, and perhaps temperature, quiescence, and the contact of particular substances, would always display themselves in our sulphureous waters. For the distinct determination of the forms and relations of these organic objects by the microscope, we owe our thanks to Dr. Lankester.

the thermal, occurs Dibbrell's Spring, a cold alkalino-sulphureous water, such as *characterizes* the lower and more calcareous portion of these slaty rocks.

The discharge of water at Wilson's thermal is abundant, but is accompanied by very little gas. The spring contains a small amount of uncombined carbonic acid, together with a considerable proportion of saline matter.

Section VIII. *From Bath across the Cacapon Mountain.*

The Cacapon or Capon Mountain, formed by the union of several contiguous parallel axes, which arise at various points within a distance of fifty miles from the Potomac river, attains its greatest altitude and breadth about eighteen miles southwestward of the line of our Section, beyond which, in its prolongation towards the river, it gradually declines. Where most largely developed, a slight roll of the strata makes its appearance near its southeastern base, which, soon assuming more importance, forms the distinct anticlinal of Warm Spring Ridge. This, in its prolongation towards the northwest, gradually loses its anticlinal character by the obliteration of the narrow trough between it and the Cacapon axis, and forms at the Potomac a low flanking hill of southeast dipping rocks. Where the thermals of Bath arise, the anticlinal flexure is still in part preserved in a sharp but transient change of dip in the rocks a little westward of the Springs. Owing to an error in reducing this Section, the space between the centre of the Eastern Cacapon axis and the position of the springs, is much too great. Contracting this interval, it will appear that the position of these thermals agrees in all important points with that of the springs on the southeastern flank of the Mill Mountain, Section I, and of the group in Section IV.

These copious springs make their appearance near the junction of Fors. VII and VIII, at the southeastern base of the Warm Spring Ridge, here faced by the massive jointed sandstone of the former. The gas which accompanies the water, though consisting mainly of nitrogen, contains a rather larger proportion of oxygen than is found in the other principal thermals of the State. The amount of solid matters present in these waters is extremely small.

SECTION IX. *From the Cacapon Springs to the Little North Mountain.*

SECTION X. *From the Great North to the Little North Mountain, through Bon Springs.*

In the former of these Sections, we have a view of the folded or inverted form of flexure, both in the anticlinal of the Paddy and Great North Mountain, and in the trough between the former and the Little North Mountain. In the narrow anticlinal valley hemmed in by the wild and rugged heights of the Paddy and Great North Mountains, no decidedly thermal springs have yet been discovered, though the structure and topography of the place would seem highly favorable to their production. Perhaps their absence may be explained by the peculiarly shattered condition of the strata occupying the surface of the valley, and forming the enclosing mountains, especially that on the northwest, in virtue of which ready channels may be furnished conveying them to other and remote points of discharge. This opinion is, I conceive, supported by the conditions under which the Cacapon Springs occur. These thermals, as indicated on the Section, make their appearance on the northwest side of the Great North Mountain. They are four in number, and situated at different levels, the lowest, which is also the warmest, flowing from For. VII, near its junction with VIII, and the others successively lower in temperature and higher in position, issuing from VI and V. They are all copious and constant, and yield but little gas. In the lower or principal spring, the chief ingredients are carbonates and sulphates of lime and magnesia, and sulphate of soda.

SECTION X, parallel to the preceding, and a few miles northeastward of it, includes, it will be seen, three separate localities of thermal springs, the first or Pearce's Spring, (Table II, No. 40,) at the western base of the Great North Mountain, the second or Bon Springs, (Nos. 29, 30, 31,) in the Cedar Creek Valley, and the third, an unnamed spring, (No. 51,) rising near the eastern base of the Little North Mountain, all comprised in a distance which, in a direct line, is less than six miles.

On comparing the two Sections it will be seen, that the anticlinal valley of the Paddy and Great North mountains contracts towards the northeast, the inversion on its northwestern side being at the same time replaced by steep northwestern dips. This change goes on augmenting, until, at no great distance northeast of the present section, the valley terminates in a great anticlinal mountain of normal flexure, formed by the now united rocks of the Paddy and Great North mountains. While this change is in progress, two small axes, commencing a little northeastwards of Section IX, make their appearance in the Cedar Creek Valley, lifting For. VII and then VI, from beneath the slate, and forming the low range called the Sugar Hills. It is in the more important of these axes, that the *Bon Springs* are situated. This is a sharp anticlinal, giving exit to the water through For. VI. The spring to the east of this flows from the limestone near the southeastern base of the Little North Mountain, issuing as before noticed from a line of inversion and fault. *Pearce's thermal* agrees in position, as regards the axis, with the Cacapon Springs, rising near the junction of steep-dipping VI and VII.

All these springs evolve more or less gas, chiefly nitrogen, and the Bon Springs contain a considerable amount of calcareous and magnesian salts.

Deeming the preceding details sufficient to illustrate the conditions under which the various classes of thermals in Virginia present themselves, it would be unnecessary, as well as tiresome, to enumerate similar particulars in regard to the numerous other warm springs referred to in the preceding tables. I may here, however, remark, that but few of our thermals, not flowing in axes, rise, as in the case of the Mill Mountain and Keyser's Springs, on the *southeastern side* of the axis-plane. Indeed, out of the whole number included in the tables, I know of but three groups so situated, and these are exhibited on the Sections. *All the others issue from the steep-dipping on inverted strata on the northwest side of the anticlinals*, and this may be laid down as the general *law of their position.*

Of the *mechanical and chemical agencies* concerned in the production of some of these thermal springs, I have already briefly expressed my views, while describing the structure of the Warm Spring Valley, and its enclosing mountains; and I need hardly add, that the same general explanation is equally applicable to the other thermals, situated in anticlinal valleys. In carrying out this view more in detail, and especially in applying it to cases like that of the Sweet Spring Valley, where the anticlinal axis passes into a prolonged line of fault, it has appeared to me to be necessary as well as reasonable to admit, *first*, that the subterranean channels, which operate both in furnishing the requisite supplies of water and air to the depths below, and in forwarding the thermal stream under hydrostatic pressure, must have a direction conforming in general to the strike of the rocks; and, *secondly*, that the direction of the downward flow of the meteoric waters, is in a great degree determined by the natural partings of the strata, or, in other words, by the plane of dip.

These conditions granted, it will at once appear, that in a *closed* anticlinal valley, like that of the warm and hot springs, thermals, if occurring at all, might be expected to appear along its whole length, in a linear arrangement, and near its western boundary. It would also seem, in this case, that the height of the comparatively elevated ground at the two ends of the valley would determine the hydrostatic column employed in bringing the water to the surface.

Where, however, the valley is *closed only at one end*, as in that of the Sweet Springs, the case is, I think, different. Thermals may of course be looked for towards the closed end, and in this position they are found; but it is a remarkable fact, that the line of fault constituting the prolongation of the axis of the Sweet Springs, though continued to a distance of more than fifty miles, *does not disclose a single thermal* throughout its whole extent, nor have I yet succeeded in discovering more than one spring of the kind, in other parts of the Appalachian chain, where similar geological conditions prevail. On the other hand, in the prolonged line of fault running along the southeastern base of the Little North Mountain, close to the northwestern margin of our great Limestone Valley, and at other points, where the same structure exists, many thermals have been detected, several of which, from their marked elevation of temperature, are included in the preceding catalogue.

These results are, I think, sufficiently explained by reverting to the two conditions above specified, in connection with the form of the surface, and the position of the strata in the vicinity of these faults. In the *first* case, where For. II. rests upon the overturned beds of For. XI, the strata composing the narrow belt of the former, along the northwest base of the great range of Peters's and East River Mountain, and southeast of the line of fault, as well as the rocks of these ridges, dip at a moderate angle towards the southeast, and therefore *away from the fault.* On the opposite, or northwestern side of the fault, the country is comparatively *level*, the Little Mountain, which formed the western boundary of the Sweet Spring Valley having been ingulfed in the vast hiatus. Hence, though the rocks of XI, for a short distance northwest of the dislocation, (through the breadth over which this formation continues inverted,) actually dip towards the fault, the flat topography on the northwest is not such as naturally affords a hydrostatic column sufficient to raise the water from a great depth to the surface, along the line of fracture. Nor could we expect the heights of Peters's Mountain on the southeast to furnish such a column, since the *southeast dip* of the strata there would rather *oppose* than facilitate the passage of the liquid towards the fault, and would most probably convey it to subterranean tracts lying still further towards the southeast. There is also another feature, to which, as I conceive, some influence is to be ascribed in preventing the occurrence of thermals along this line. The strata of For. XI, although overturned where they are in contact with For. II, continue in this position across but a *narrow belt* towards the northwest, and by a rapid curvature below are soon brought into a very gentle northwest dip, or into a horizontal attitude. Their upturned edges could receive directly from the atmosphere but small supplies, and these, most probably, in part at least, would be conveyed away towards the gradually declining level on the northwest.

Turning now to the *second case*, of which we have an example in the fault adjacent to the southeastern base of the Little North Mountain, we at once discern this important difference, that while the direction of the dip and inversion is the same as in the preceding, the *high grounds* of the Little North Mountain lie to the *northwest.* Hence the downward drainage between the strata on the flank of this ridge, conforming to the southeastern dip of the rocks, must be *towards the fault*, and the hydrostatic columns communicating with the heights, and following the plane of dip, will in many cases have sufficient power to force up the heated waters to the surface, at certain points along or near this line.

The numerous class of thermals whose point of issue is *exterior* to the bounding ridges of an anticlinal valley, owe their origin, as I conceive, to the same general agencies as have been above considered. Bearing in mind, that in the great majority of cases they flow out from the *northwestern* boundary, the vertical or inverted rocks of which are greatly shattered, and that their point of exit is generally *below* the level of the valley, it is reasonable to suppose that, in many instances, they have been conveyed away from beneath the surface of the valley, when, in a less fissured condition of the strata towards the northwest, they would have been forced to rise at some point within its confines. In many cases, too, the downward drainage of the northwestern ridge itself is fully adequate to carry the requisite amount of fluid to the seat of heating and chemical action, and, by hydrostatic power, to raise it again to the surface at a much lower level.

In speculating with regard to those thermals which issue at or near the base of a continuous anticlinal mountain, it is important to bear in mind, that while cracks and partings are found generally attendant upon flexures of the strata, these openings are by far the most numerous and extensive in that part of the curve where the change of direction is most abrupt. Hence they will be found descending in the interior of the mountain, much in the direction of the *axis-plane*, and will lie nearer to the northwestern than the southeastern side. The meteoric waters supplied through these channels, will find an exit either by the natural slope of the gently dipping rocks on the southeast of the anticlinal, or through the fissures of the shattered and steeply inclined or inverted strata on the northwest. Where but little of this fissuring occurs on the northwest side, they would meet with least obstruction by flowing in the opposite course, and might, therefore, be looked for on the southeast. Such would seem to be the case with the thermals of the Mill Mountain and Keyser's, (Sections I, and IV,) where the steeply inclined strata are comparatively entire. But, as formerly remarked, the usual position of thermals is on the other side of the anticlinal axes.

It may here be added, that where such springs present a temperature but little above the atmospheric mean, it is unnecessary, in accounting for their heat, to suppose that the water has been conveyed to any very considerable depth below the base of the mountain, as the subterranean line of equal temperature (chthonisothermal line), deflected *upwards* by a massive and steep anticlinal range, would come nearer to the general surface.

Such is a sketch of the views to which I have been led in considering the positions occupied by our thermals, in connection with the probable mechanical agencies by which their waters are accumulated and brought to the surface. Though in some degree hypothetical, as must be all attempts at explaining the unseen mechanism of nature, they are, I think, in harmony with observation, and at all events possess the merit of agreeing in general principles with doctrines sanctioned by the authority of such names as Arago and Bischoff.

As regards the *evolved gases* and the *chemical ingredients* of these springs, my opinions, like those of others who have speculated on this subject, are, confessedly, far from satisfactory. While I am inclined, in some respects, to agree with the views which have been so ably advocated by Dr. Daubeny, in relation to the origin of the gases and other matters associated with thermal waters, I am by no means prepared to adopt the hypothesis, that such impregnations are chiefly due to the *chemical action of the metallic bases of the alkalies and earths;* much less can I accede to the opinion, that the *heat* of our thermals, as well as that of the rocks from which it is directly derived, is due to what is usually termed *volcanic action.*

Deferring my objections to these views to a later head, I would venture to throw out a suggestion as regards the evolution of *nitrogen* from these and other thermals, which appears to me not unworthy of consideration. Admitting, with Dr. Daubeny, what I think extremely probable, that this gas, as it appears in thermals, is but a *residuum* of the atmospheric air which, conveyed from the surface to the source of heat below, has there been partially or entirely deprived of its oxygen, I would inquire, whether the composition of the rocky beds through which the atmosphere is thus conducted is not itself capable of explaining the result.

The limestone For. II, and the slates forming a part of For. I, always contain more or less protoxide of iron and carbonaceous matter, even after long exposure to the action of the weather. Where freshly taken from a new excavation at some depth, the latter rocks abound in the protoxide, and the limestone exhibits nearly all its iron in that stage of oxidation. It would therefore seem probable, that these and the other strata deposited beneath the Appalachian sea, contain, at great depths, this oxide to the exclusion of the sesquioxide. Looking to the large accumulation of the latter in a hydrated state, segregated in various parts of these several formations, it is not unreasonable to infer an even greater proportion of the protoxide in the deeply buried strata than would correspond to the whole quantity of iron combined in the rock above. That the presence of diffused organic matter, such as we know to have been deposited with the other materials of the strata, would secure the protoxide from further oxidation, while still in contact with the waters of our great Appalachian ocean, is a result in harmony with what we witness in our present seas, and with the known chemical relations of the substances concerned. Conceding, then, the existence of the protoxide in due proportion in these older formations, and imagining the air to obtain access to these strata at a depth at which the temperature is sufficiently high to cause a rapid absorption of the oxygen by the protoxide, we should have a large amount of the residuary nitrogen evolved. The carbonaceous matter* also would help to rob the air of oxygen, and aid in the production of the carbonic acid, by which the nitrogen is uniformly accompanied, although it is to the calcination of calcareous rocks that, in common with others, I would refer most of the carbonic acid which our thermal waters contain.

The conjectures thus thrown out, though, as I think, not entirely useless, are offered with that distrust which must always attach to speculations that cannot be brought to the touchstone of actual observation, and more especially, too, from the fact, that they do not appear to have suggested themselves with any force to the able philosophers who have investigated this subject. That I may not be misconceived, I here beg to remark, that I have no disposition to *deny* the hypothesis of the metallic bases, as applied to volcanoes, or even to some thermal springs. On the other hand, I would adopt it as a *part* of the general theory of the causes concerned in the formation of the early crust of the globe from a molten, and chiefly metallic mass. But, in this *later stage* in the history of our earth, I would venture to doubt the propriety of resorting to it in explaining the phenomena of thermal waters in general, and more particularly of those to which my own observations have been directed; and I would give a hearty welcome to any theory which, dispensing with the necessity of penetrating to such enormous depths in search of the unoxidated metals, would explain the chemical characters of these waters by *the known properties of the rocks*, in connection with *a generally diffused internal heat.*

In considering the bearing of the preceding details respecting the thermals of Virginia upon the doctrine of a general subterranean heat, as compared with that of local foci of volcanic action, there is one fact in the geology of our Appalachian region, par-

* Quickly volatilized and combined with oxygen, its power to arrest the oxidation of the protoxide, or to reduce the peroxide when formed, would not, I conceive, be called into play. But even if it were, the difficulty would not be so great as where potassium and sodium are regarded as among the chief oxidizing agents. For in this latter case, what becomes of any carbonic acid which, evolved at the focus of activity, is brought in contact with these metals?

ticularly deserving of attention. I mean, *the almost entire absence, over its vast surface, of igneous or volcanic rocks.* These occur at only four or five points, without any observable relation to axes, and away from the neighborhood of any known thermals, and are in such small amount as together not to cover an area of more than ten acres. Add to the preceding this further fact, that our thermals are not confined to particular lines or axes, but *are scattered at remote points over the whole region*, and it will at once appear, with how much more reason they may be referred to a pervasive subterranean heat, than to points or lines of volcanic action. To apply the latter explanation, we must give to these local foci a *diffusion* beneath the surface, which would, in fact, amount to abandoning the doctrine of merely local heating action, and admitting that of a general internal heat; while, in adopting this latter, we see, in the peculiar positions of our thermals in reference to axes, *simply those mechanical conditions which favor the access of air and water to the deep-seated, and therefore hot strata in the interior, and their expulsion at the surface.*

Adopting the language used by the eminently philosophic Phillips, when referring to arguments urged in favor of the hypothesis of local volcanic action, as the cause of thermal springs in general, I would say, " These arguments, when taken in connection, appear to us to prove, that the heat of the springs is derived from the *depths of the channels* in which they flow below the surface," and "it seems unnecessary to appeal to local volcanic excitement for an effect which spreads, both in time and area, far beyond the traces of purely volcanic phenomena." Such being the inferences of one of the ablest of geologists, from a comparison of the chemical and geological relations of the thermals of the old world, with what *augmented* force may they not be reiterated, after the preceding developement of these relations in a region which, like our Appalachian chain, is almost destitute of even a trace of proper volcanic action!

NOTES ON THE GEOLOGY OF SEVERAL PARTS OF WESTERN ASIA: FOUNDED CHIEFLY ON SPECIMENS AND DESCRIPTIONS FROM AMERICAN MISSIONARIES. BY EDWARD HITCHCOCK, LL. D., *Professor of Chemistry and Natural History in Amherst College, Massachusetts.*

FOR several years past, I have from time to time received specimens of rocks and minerals from American missionaries located in Western Asia, often accompanied by full descriptions. My collection from that part of the world (including about one hundred specimens from India, Ceylon, and China, sent by Rev. E. Burgess, N. Ward, and E. C. Bridgman, also missionaries) amounts to six hundred and sixty-two specimens: and, since the geology of those countries is so little known, it has seemed to me that these specimens and descriptions would enable me to present to this Association some Notes concerning it, that might be of value. We cannot, indeed, expect to obtain, from specimens thus sent, a regular history of the geological structure of those wide regions; but even glimpses may be important, and assist future explorers. Specimens have been received from the following gentlemen; most of whom I have known in the interesting relation of pupils:

Rev. JUSTIN PERKINS, located at Ooroomiah, in Persia.
" STORY HEBARD, at Beyroot, in Syria.
" BENJAMIN SCHNEIDER, at Broosa, in Asia Minor.
" OLIVER PHILANDER POWERS, at Broosa, in Asia Minor.
" HENRY HOMES, at Constantinople.
" JAMES L. MERRICK, at Tabreez, in Persia.
" HENRY J. VAN LENNEP, at Smyrna.
" J. J. ROBERTSON, D. D., at Athens and Constantinople.
" CYRUS HAMLIN, at Constantinople.
Mr. ALEXANDER G. PASPATI, at Constantinople.
" HOMAN HALLOCK, at Malta and Smyrna.

I ought to mention, also, the valuable information which I have obtained from the recent very able and learned work, entitled 'Biblical Researches in Arabia, Palestine, and Syria, by Professor Edward Robinson of this country, and Rev. Eli Smith, American Missionary at Beyroot.' I have been allowed, also, to have access to several rare specimens deposited in the Collection of the American Board of Commissioners for Foreign Missions in Boston.

Most of the gentlemen whom I have named, would disclaim all pretensions to practical skill in geology. But of one of them, from whom I received the largest number of specimens, I may speak with more freedom, since he is no longer among the living. I refer to the Rev. STORY HEBARD. Were this the proper place and occasion, it would afford me great pleasure to bear public testimony to his amiable and gentlemanly character and high moral worth, as a tribute to the memory of a beloved pupil and friend. It is, however, proper to say, that, having devoted himself to the profession of a teacher, he gave special attention to chemistry, mineralogy, and geology. With this view, he became my assistant in the laboratory, and in the geological survey of Massachusetts. When he went out to Syria, therefore, I could not doubt that he would give special attention to the geological structure of that country, so far as he could, consistently with the higher duties of his benevolent mission. And the box of specimens which I received from him, gave ample evidence of the extent of his researches, especially on Lebanon and Anti-Lebanon. I have reason to suppose that he was engaged in a systematic examination of that region, with the intention of giving the result ultimately to the world. But whether he left any notes on the subject, I am not informed. I am not without fears, however, that the imperfect notices which I shall give in this paper, may prove almost the only public memento of this department of his labors. He was just commencing a course of lectures on geology and natural history to the Arabic youth, in the seminary of which he was the head. But an inscrutable Providence has terminated, in a manner that seems to us premature, his worldly plans and labors, and the expectations of his friends; leaving to them only the melancholy duty of gathering up the fragments of his scientific efforts, and dedicating them to the dead.

In giving an account of the specimens and facts in my possession, relating chiefly to Western Asia, it will promote brevity, to arrange the countries from whence they came into groups.

The first group will embrace Egypt, Arabia, Palestine, Syria, and the island of Malta.

The second group will comprehend several districts in the western part of Asia Minor, and a few islands in the Grecian Archipelago.

The third group will include Armenia and Persia.

My specimens from Syria, amounting to more than one hundred, were furnished by Mr. Hebard: those from Palestine, by Messrs. Hebard and Homes: those from Egypt, and the Grecian islands, chiefly by Dr. Robertson: and those from Malta, by Mr. Hallock. The numbers by which the specimens will be indicated generally in this paper, are those which they bear in my cabinet, which is deposited in Amherst College.

Before proceeding to details, I ought to remark, that I have not had an opportunity of perusing, except in condensed notices, several recent papers and volumes concerning the countries from which my specimens came, and which doubtless contain many statements respecting their geology: such as the papers of Botta, Strickland, and Hamilton, upon Syria and Asia Minor; and the travels of Schubert, Hamilton, and Ainsworth. In some cases, therefore, my remarks may have been anticipated. But it would be strange, if some new facts should not be derived from a source so entirely independent of the one just mentioned as that from which my information comes, in countries whose geology is so little known. And, besides, the two sets of observations may serve to correct or confirm each other.

I begin with a few remarks upon the peninsula of Sinai and Arabia Petræa; chiefly because we find there a granite nucleus, as striking as any on the globe. It has long been known that the lofty and naked group of mountains that have received the general name of Sinai, are mainly composed of granite, or rather of syenitic granite. The highest peak, called St. Catharine, is eight thousand and sixty-three Paris feet above the ocean. A specimen from this mountain, in the collection at the rooms of the American Board of Foreign Missions in Boston, is a gray syenite, the specks of hornblende being considerably numerous, but small. It contains no mica. Another specimen from the peak that goes by the name of Horeb, is reddish, and contains very little hornblende. This summit is very probably the Sinai of Scripture, where the moral law was given: and though these mountains have been visited by so many sagacious travellers, for many hundred of years, and inhabited by learned monks, yet it is a curious fact, that this spot should be first identified in the nineteenth century, by two American travellers: and that Messrs. Robinson and Smith have identified it, will, I think, be manifest to any one who will carefully examine their researches.

I noticed at the Missionary Rooms, a crystal of quartz from Mount St. Catharine, three quarters of an inch in diameter, incrusted with minute crystals of epidote: also fibrous red hematite from Fursh el Khijan, two hours east of Wady Bijah in Mount Sinai. In the same collection is a specimen of rock salt, from the "Head of Wady el Tayibah, where the Israelites turned to encamp by the Red Sea." Dr. Anderson allowed me to take the fragment No. 424 for chemical examination. I suspected from its aspect that it might be a recent deposit; but careful examination enabled me to find in it several fragments of chalky limestone; and hence I suspect it to occur in that rock; which, as we shall see, is connected with the rock salt near the Dead Sea. A solution of the specimen from Sinai, gave a distinct precipitate to chloride of barium, to oxalate of ammonia, and ammoniaco-phosphate of soda; showing the presence of a sulphate, also lime and magnesia: but in less quantity than is usual in fossil rock salt. I could detect in it neither iodine nor bromine. I have no information as to the extent of the deposit.

The syenite of Sinai is traversed by many dykes of trap rock, probably greenstone; and in approaching it from Egypt, Robinson and Smith describe a formation of porphyry. In passing from Sinai to Akabah, they described the hills of granite as frequently capped in a singular manner with sandstone. In the great desert between Sinai and Palestine, the hills appear to be mainly composed of limestone, chiefly the chalky variety, and probably belonging to the cretaceous formation. Sixty or seventy miles northeast of Akabah, which stands at the head of the eastern branch of the Red Sea, is the remarkable gorge where once stood the capital of Edom, now called Petra. And from the descriptions given us by those who have visited it, we must consider it highly probable, that the rock forming the gorge is the new red sandstone; though no organic relics have been described in it. This formation probably also extends southerly far towards Sinai, and northerly an unknown distance.

It would not be strange if the syenite of Mount Sinai should be found to extend continuously beneath the Red Sea, to the famous quarries of red granite at Syene, in Upper Egypt. In regard to the latter rock (No. 107) it may perhaps appear presumptuous in me to suggest the suspicion, that some of it ought to be regarded as gneiss. This thought first occurred to me, on examining a similar rock in southeastern Massachusetts; which I at first supposed to be granite, but afterwards became satisfied was granitic gneiss. This suggestion, however, is not of much importance: for often there is not a more difficult point in geology, than to draw the line between granite and gneiss. Yet I find that the more I examine, the more disposed I am to reduce the limits of granite, and enlarge those of gneiss.

We have all heard much of the deserts of Arabia, and of the moving sand-hills there. No. 553 is a specimen of these sands: and, on examination with the glass, I was surprised to find them to consist of fragments of genuine yellow quartz, not to be distinguished by the eye from topaz. The grains are very much rounded. Was this done by water, or by wind, or by both? This specimen was presented by the Rev. Justin Perkins of Persia; to whom it was given by a Mahommedan pilgrim, on his way from Mecca, or Medina, to Persia. He stated, that the caravan was a fortnight in crossing these sands.

My specimens from Egypt are too few, perhaps, to throw any light upon the geology of that country. The silicified wood, No. 396, is the most interesting. This is from the extensive deposit near Cairo. "For miles," says Dr. Robertson, "the surface is covered with fragments, from the size of this specimen to many feet in length." The texture of the siliceous matter is much coarser than that of the well-known specimens from Antigua: so coarse, indeed, that Professor Bailey could not detect the minuter vessels of the wood by a microscopical examination. The concentric layers, however, are very distinct to the naked eye, as well as the medullary rays, with no appearance of parenchymatous tissue. We may hence safely refer this specimen to an exogenous dicotyledon; and with nearly equal confidence to the tribe of coniferæ; and very probably it may belong to tertiary strata. The fossil crab, No. 386, from near Cairo, and the nummulites, No. 387, from the pyramids of Gizeh, are interesting chiefly from their localities. Dr. Robertson refers the former to tertiary limestone; and I notice that his specimens are usually named with great accuracy. No. 394 is a quartzose conglomerate from the mountain Djebel Aschar, near Cairo. No. 385 is beautiful, calcareous, translucent alabaster, which is employed by the Pasha of Egypt in building a palace at Cairo. This rock has evidently been deposited from springs, like the famous alabaster near Tabreez in Persia, to be hereafter described; but I have not been informed of the Egyptian locality. This alabaster is entirely soluble in nitric acid, except a mere trace of earthy matter. And I was surprised not to be able to detect in it any iron or magnesia; substances considerably abundant, as we shall see, in the Persian alabaster. It may, therefore, be considered a pure carbonate of lime; and I regret not to know its locality.

Whoever receives specimens of rocks from the countries bordering on the Mediterranean, will be struck with the predominance of limestone over all others. And he will notice a striking identity of characters in those from different countries. My specimens exhibit three distinct varieties. The first are chalky and pulverulent, of a white or yellowish color, and in fact pass into true chalk; the second are compact and yellowish; and the third are highly crystalline. The last class is always associated, as in this country, with gneiss or the older slaty rocks. The first class belongs either to the tertiary or cretaceous groups, — more commonly to the latter; and the second class, I strongly suspect, will be found to correspond to the Öolitic group of continental

Europe. The first and second classes will first demand our attention.

We now know enough of the rocks around the Mediterranean to be certain, that these compact and chalky limestones extend through a considerable part of Egypt, thence into the northern part of Arabia, thence through Palestine and Syria to Mount Lebanon and Anti-Lebanon, which are mainly composed of these rocks. Similar rocks occur, also, in the island of Malta; and the compact variety, at least, in Greece and Asia Minor. Out of the large number of specimens in my collection, I have examined a few analytically; chiefly, however, with a view to determine whether any of them are dolomitic.

In No. 15, which is the common rock of Mount Lebanon, according to Mr. Hebard, I found in one hundred parts, by a not very satisfactory analysis, although repeated,

Earthy residuum,	1.0
Carbonate of lime,	61.3
Carbonate of magnesia,	37.7
	100.0

No. 25 lies below the conglomerate and chalky limestone, one mile west of Damascus; and I found in one hundred parts,

Earthy residuum,	0.33
Carbonate of magnesia,	4.13
Carbonate of lime,	95.54
	100.00

No. 5 is the rock on which Jerusalem is built; and it was used in building the Temple of Solomon, some of whose foundation-stones still remain, as seems to be made very probable by the researches of Robinson and Smith in that city. One hundred parts of this stone gave

Earthy residuum,	1.00
Carbonate of magnesia,	0.83
Carbonate of lime,	98.17
	100.00

No. 54, from the supposed site of the garden of Gethsemane, appears to be an agatized mass of silica, containing a little carbonate of lime. In one hundred parts I found

Earthy residuum,	95.33
Carbonate of magnesia,	1.67
Carbonate of lime,	3.00
	100.00

An argillaceous limestone, one mile west from Damascus, yielded in one hundred parts,

Earthy residuum,	69.67
Carbonate of lime,	30.33
	100.00

The red compact limestone, No. 89, from Wady el Hareer, in Anti-Libanus, yielded in one hundred parts,

Earthy residuum,	3
Carbonate of lime,	97
	100

No. 29 was broken from the rock a few feet from the cave of Machpelah in Hebron, where Abraham was buried: a spot better identified than almost any other holy place in Palestine. One hundred parts gave,

Earthy residuum,	0.33
Carbonate of magnesia,	6.33
Carbonate of lime,	93.34
	100.00

These analyses show us, what indeed we might have expected, that the limestones under consideration have been but slightly dolomitized. That from Lebanon contains, indeed, a large proportion; but it would be desirable to know its precise location before we conclude the whole of that mountain to be as highly charged with magnesia.

I could have had but little hope of being able to refer to their true place, in the geological scale, these insulated specimens of limestone, collected by different individuals in distant lands. But through the liberal assistance of Professor Bailey, and his great skill in the use of the microscope, I am enabled to assign to a part of them, at least, a place among the rocks, with confidence. The following paragraph, from Mr. Weaver's Observations on the Discoveries of Ehrenberg, contained in the Annals of Natural History for June, 1841, did, indeed, furnish the clue to the results at which we have arrived.

"The compact limestone rocks which bound the Nile in the whole of Upper Egypt, and extend far into the Sahara or Desert, as well as the west Asiatic compact limestones in the north of Arabia, are in the mass composed of the coral animalcules (Polythalamia of Ehrenberg, the same as the Foraminifera of D'Orbigny) of the European chalk. This affords a new insight into the history of the formations of Lybia, from Syene to the Atlas, and of Arabia, from Sinai to Lebanon."

The perusal of this paragraph led Prof. Bailey to request me to send him specimens. This was done, and very soon he was so obliging as to return the following interesting results:

"I hastened," says he, "to examine microscopically the powders which you kindly sent, and obtained the following results:

"No. 136. From the Pyramid of Cheops, near Cairo: Polythalamia distinctly present, but rare.

"No. 2. Chalky limestone, west side of Anti-Libanus: Polythalamia abundant.

"No. 13. Limestone one mile west of Damascus: Polythalamia abundant.

"No. 5. Chalky limestone, Mount of Olives: Polythalamia abundant.

"No. 6. Do. Beyroot. Polyathalmia present, but not so abundant as in No. 5.

No. 30. Argillaceous limestone, river Barida, Anti-Libanus: Polythalamia abundant.

"This examination then confirms Ehrenberg's statement with regard to the presence of coral animalcules (Foraminifera of other writers) in the limestones of Arabia. His statement refers to the compact limestones, which he says are thus composed, 'from Sinai to Lebanon.' I do not see, in Weaver's abstract of Ehrenberg's views, any notice of the occurrence of these shells at Jerusalem, or Damascus; but I doubt not, that the rock at these localities forms part of the same series which was observed by Ehrenberg 'at Hamam Faraun and Tor, in the Sinaian portion of Arabia,' 'constituting hilly masses in Upper Egypt,' and 'continued eastward far into the interior of the Great Desert plain, trending eastward toward Palestine.' Damascus is a point further to the north and east than Ehrenberg mentions. How interesting the thought, that the Mount of Olives, and probably the Holy Sepulchre itself, was formed by these minute creatures, of which more than a million exist in every cubic inch of the rock!'

" Having determined the presence of these creatures in the specimens, I next endeavored to ascertain if they would afford any evidence as to the geological age of the formation from which they were taken. Ehrenberg had already referred the specimens examined by him to the epoch of the chalk, relying for the correctness of this statement on the identity of the *predominating forms* with those found in the chalk of Europe. With the forms of the English chalk, recent examinations have made me somewhat familiar; and I feel no hesitation in saying, that the specimens sent by you contain forms specifically identical; and to this statement I can add, that the *predominant* forms of the chalk marls from the vast regions of the Upper Missouri and Mississippi are also the same. As the prevailing Polythalamian forms of the tertiary epoch are *much larger* and of distinct species, need we hesitate to refer the Asiatic and American deposits to the cretaceous group? That the reference is correct in regard to the American deposits, you will remember was shown by the character of the organic remains of *other classes* of animals found by Mr. Nicollet.

" To enable you to judge of the close resemblance of the forms of Polythalamia, I have made, with the *camera lucida*, a series of comparative sketches. (Pl. XIII.) They are very imperfect, for, as the little shells are often considerably hidden by adhering calcareous particles, I found some difficulty in taking the outlines. Ehrenberg mentions *Textularia globulosa* and *Rotalia globulosa*, as among the chief constituents of chalk. Figs. 2 and 3, I drew from the most common forms, in a specimen of English chalk. I have little doubt, that fig. 3 is the *Textularia globulosa*, and I strongly suspect that fig. 1 is *Rotalia globulosa*. I, however, do not profess to be acquainted with the genera and species of the Polythalamia; but, whatever the names of figs. 2 and 3 may be, there can be no doubt of their specific *identity* with the forms shown in figs. 1, 3, 4, 5, 6, and 7, from Damascus and the Mount of Olives, Beyroot, and a missionary station on the Upper Mississippi. You will observe in the figures small spots, marked *a, a.* These were red spots found in the cells; possibly eggs. They are present both in the Asiatic and American specimens. The other dark spots, *b, b,* are air bubbles, left in the cells after spreading the specimens in Canada balsam.

"The scale of the drawings is the same for all. Fig. 6 shows $\frac{25}{100}$ of a millimetre, magnified equally with the sketches. No siliceous infusoria were found in any of the specimens."

These details seem to me to furnish a most interesting example of the triumph of science over difficulties, and to hold out great promise to geology from the microscope. The missionary, as he hurries over unexplored regions on his horse, or on his camel, breaks off a few specimens of the rocks he meets, giving them a place, perhaps, in his wardrobe;* and at length sends them to me, five thousand miles distant, with a label, merely indicating the locality. I inclose eight or ten specimens in a letter to Prof. Bailey, through the mail, so minute, that the most sagacious postmaster would not suspect their presence, and would not think them a breach of the law did he notice them. In a short time the microscope is made to reveal infinitessimal forms in these specimens, which fix their position in the geological scale of rocks, as satisfactorily as if they contained megatheroids or mastodons. In other words, the most difficult problem in geology, the identification of rocks in widely separated regions, is solved at a glance, and at the distance of five thousand miles from the only place where we should suppose it possible to solve it. If this is not a beautiful example of the magic power which science sometimes bestows upon its votaries, I know not where one may be found. In these remarks, I shall of course be understood to refer to the gentleman who has brought out these results; and not to myself,

* I have reason to know, that not a few of the specimens in my collection were conveyed in this manner hundreds of miles, over some of the roughest regions of Asia. Indeed, half a suit of clothes, thus freighted, in one instance came into my possession; and if they had been hung up, with their contents, in my cabinet, they would have furnished an interesting memento of zeal in the cause of science.

who have been merely the medium through which the specimens and results have been transmitted.

The developement of limestone in the wide region extending from Upper Egypt to the northern part of Syria, judging from the testimony of travellers, must be immense. Nearly all Palestine appears to be underlaid by it, and Lebanon and Anti-Lebanon are mainly composed of it. How much of this rock is the chalky limestone, I know not. But travellers describe this variety as occupying the surface to a considerable extent over the wide area above named. In most places its strata are horizontal, but in others highly inclined. Rev. W. M. Thomson, an American missionary, whom I have not mentioned, has given, in his journal in the Missionary Herald, an account of an excursion from Beÿroot to Aleppo; and in one place on Mount Lebanon, near Ant Elias, where he was accompanied by Mr. Hebard, he says, that the thick layers of marl, which are there "separated by thin strata of hard limerock," stand perpendicular to the horizon. (*Miss. Herald, January* 1841, *p.* 30.) M. Botta has described the rocks of Lebanon as consisting of three groups. The highest is composed of limestones of variable hardness, alternating with marls; the middle group embraces siliceous beds and nodules, with fossil shells and fishes; and the lowest group is mostly sandstone, with beds of silico-calcareous matter, iron ore, and lignite. He refers the whole formation to the chalk.

It may be presumption in me to raise a doubt as to the conclusion that the vast pile of mountains, nearly ten thousand feet high, called Lebanon and Anti-Lebanon, and indeed all the compact limestones from Syria to Syene, belong to the cretaceous group. But the exact identity of lithological characters between many of the specimens sent me by Mr. Hebard, and the lithographic limestone of the Jura, or Öolite group, from Germany, (specimens of which are laid upon the table for comparison,) cannot but excite the inquiry, whether the rock on which Jerusalem is built, (No. 422,) and Nos. 33 and 44 from Anti-Lebanon, 26 and 37 from near Damascus, 32 from the Pool of Siloa, and 45 from the rock at Hebron, in which is the cave where Abraham was buried, may not belong to the Öolite. In other words, whether both the Öolitic and the cretaceous groups do not exist in those regions. There are calcareous breccias and conglomerates, also, (Nos. 35, 43, and 47,) frequently lying above the compact limestone, and made up entirely of fragments of calcareous rock, which seem, from their great hardness, to belong to a formation older than the chalk. And, finally, Rev. Mr. Thomson, in his tour from Beyroot to Aleppo, describes Mount Cassius, somewhat west of Antioch, in the northern part of Syria, as abounding in primary rocks. Still further west, the marl had disappeared, and vast masses of serpentine took its place. At Mount Cassius, he describes serpentine, hornblende, and micaceous rocks, and a deposit of granite two hundred feet thick, resting on a talcose rock, that was found for miles uninterruptedly. This, to be sure, is a rather an unusual position for granite; but if it had been protruded through the talcose rock towards the top of the mountains, it would have been easy to mistake the mantling of the slate around the granite for an inferior position. Above the granite, he says, there rested a deposit of hornblende and mica. So that I doubt not the older crystalline rocks occur there. Again, No. 94 is limestone with talc from Beyroot; precisely such a rock as occurs in New England, in some of our oldest deposits. If, then, the oldest rocks exist in the vicinity of Lebanon, we may presume that the formations intermediate between these and the chalk will be found there, as in other parts of the world*.

If Botta is correct in placing the sandstones of Lebanon beneath the compact limestones, I acknowledge that the character of these sandstones corresponds very well to the ferruginous sandstone formation of this country, regarded as belonging to the cretaceous formation. They are, for the most part, highly ferru-

* *January* 1, 1843. Through the kindness of Prof. C. U. SHEPARD, I have just seen a rough section of the rocks, extending from Beyroot to Damascus, across Mount Lebanon and Anti-Lebanon, constructed by Rev. Mr. LANNEAU, American Missionary at Jerusalem. He represents three principal deposits through the whole distance; namely, conglomerate at the top; beneath this, chalky limestone; and compact limestone the lowest of all. Such a position of the latter corresponds with the suggestion in the text, that it may belong to the öolite group. He places the sandstones quite high upon the mountains, above the compact limestone.

ginous, and easily crumbled down. Nos. 79, 80, 81, 82, 83, 87, 88, and 98, will convey a good idea of their character. No. 98 overlies an interesting mineral, (No. 99,) which I believe is regarded in Syria as bituminous coal. Such, indeed, I should have considered it, had I not subjected it to analysis, when I found its composition as follows, in one hundred parts:

Bitumen, or volatile matter,	68.0
Carbon,	24.4
Earthy incombustible matter,	7.6
	100.0

Now I believe that no bituminous coal, occurring in regular beds, contains near as much volatile matter as this specimen. Indeed, its composition corresponds very well with that given for asphaltum. And yet it conducted quite differently, when heated in a platinum bowl, from a specimen of true asphaltum, (No. 100,) from Gebel Es Shakh, on Mount Hermon, which is a part of Anti-Libanus. The latter specimen easily melted; but the former did not melt at all. The specimen from Hermon, however, did not differ very much in composition from the one taken from Lebanon. In 100 parts I found

Bitumen, or volatile matter,	72.6
Carbon,	14.0
Earthy residuum,	13.4
	100.0

These analyses will, I think, justify the inference, that these deposits of bitumen can have little bearing upon the question of the age of the rocks containing them; for they are probably of volcanic origin. The character of the lignites occurring in the same series, at Brumanah on Lebanon, is not different from that of common lignites, and the accompanying shales are mere friable clay, impregnated more or less with carbon. See Nos. 69, 70, 71.

None of the specimens sent me appear to be genuine chalk, but rather chalky limestones, or marls. Nor have I seen any genuine chalk described as occurring in any part of this vast cretaceous formation. The specimens sent by Mr. Hebard under the name of flint, Nos. 72 to 76, appear to be rather chert or hornstone passing into flint.

The organic remains found on Lebanon and Anti-Lebanon are considerably numerous, and quite interesting. The most so, probably, are the fossil fishes from Hakil, on Lebanon. They are found on a light-colored marl slate, resembling that of Monte Bolca, though harder, (No. 91.) They are usually rather small, and have decidedly homocercal tails, as we should expect. But I need not dwell upon them, since they have been described by Agassiz, in his *Poissons Fossiles*, and referred to the cretaceous formation. At Alich, on the same mountain, occur numerous specimens of the nuclei of at least two species of Venus (Nos. 647 to 653); also of an Isocardia, (No. 654,) perhaps the minima (*Goldfuss*, Tab. 140, fig. 18); also of an Arca (No. 655); also of a Strombus (Nos. 656, 657); also of a Rostellaria (Nos. 658, 659, 660, *Goldfuss*, Tab. 170, fig. 6); also of a Natica? (No. 661;) also of a Spatangus, (No. 662, *Goldfuss*, Tab. 46, fig. 2.) No. 40 is a Caryophyllia from Lebanon; No. 51 an Hippurites from Ain Nab, on that mountain; and No. 52 a large species of Terebra from Babda, on the same. Many of these may be new species; but I do not feel competent to decide that question without access to more numerous authorities than are at present within my reach.

The siliceous nodules occurring in the middle group of limestones of Lebanon, are often very fine and beautiful. Some of them, as Nos. 62, 63, and 334, appear externally rough, and devoid of all beauty. But, on breaking them open, they present rich geodes of crystallized quartz, with crystals of calcareous spar, sometimes implanted upon the quartz. Those which I have seen vary in size, from that of a man's fist to that of his head. From the number sent to this country, I infer that they are very abundant. Another variety consists of fine geodes of chalcedony. No. 58, which is six or eight inches in diameter, is found a little northwest of Safet, where it is very abundant. This is a region, as we shall shortly see, where volcanic action has been powerful; but whether this has any connection with the production of the chalcedony, I know not; for these geodes appear to have been formed in the limestone. Yellowish crystallized carbonate of lime appears to be common in Lebanon, having the columnar structure exhibited by Nos. 64 to 68. Near Aleppo, according to Mr. Thomson, are large beds of gypsum; and from this are obtained fine plates of selenite, such as No. 59.

I have not yet mentioned a remarkable variety of limestone, found on the west shore of the Dead Sea. It is nearly black, perfectly homogeneous and compact, and contains a large proportion of bitumen, (Nos. 77 and 145.) On this account, it admits easily of a polish, and is employed at Jerusalem for the manufacture of rosaries and other small articles. I found its composition, in one hundred parts, to be,

Bitumen,	25.00
Carbonate of lime,	68.73
Carbonate of magnesia,	0.27
Earthy residuum,	6.00
	100.00

From this analysis I draw two inferences. The first is, that if this rock can be obtained in abundance, it may prove valuable in the formation of a cement for pavements, and other purposes; having in fact a very similar composition to the artificial compound employed in that manner. The only difficulty seems to be in getting rid of the carbonic acid, as sufficient heat cannot be applied without destroying the bitumen. I have, however, no suggestion to make on the subject. My second inference is, that this limestone ought to be regarded as a mineral species, distinct from carbonate of lime. All the bituminous carbonate of lime hitherto described, except that from Dalmatia, which is probably the same as that from the Dead Sea, contains so little bitumen, that it has been supposed an unessential ingredient; but in this case, it forms a quarter part of the stone, and there can hardly be a doubt but it exists in the compound in a definite quantity. Yet, as the combining proportion of asphaltum does not seem to be ascertained, we cannot test the composition by this rule. I venture to propose it, however, as a distinct species in mineralogy. In what quantity it exists at the Dead Sea, I cannot learn, Robinson and Smith found it in descending from the promontory Ras el Feshkah to the plain, near the north end of the sea; and, in one instance, it formed the cement of pebbles, as if it had flowed in among them. But such is often the appearance of the cement of conglomerates; and the rock in that region is mostly conglomerate. I apprehend that this limestone, as well as the conglomerate which it forms, were produced at the bottom of waters abounding both in carbonate of lime and fluid bitumen. It occurs in large quantities on the west shore of the Sea of Galilee, whence several thermal springs issue; and not improbably, a careful examination of that locality might show that it is now in the course of formation, and unfold the precise mode of its production.

The compact limestone, No. 380, from Mars Hill in Athens, I analyzed, partly on account of its classic locality, and partly to see whether its composition agrees with that of the compact limestones of Western Asia. In one hundred parts, I found

Earthy residuum, ...	2.33
Carbonate of magnesia, ...	0.84
Carbonate of lime, ...	96.83
	100.00

It will be seen, by comparing the above analysis with those previously given, that it corresponds closely with that of several of the compact limestones of Palestine and Syria.

The common rock of the island of Malta, Nos. 140 and 141, very much resembles some of the chalky limestones of Syria and Palestine. But Professor Bailey could not detect in it any Polythalamian remains; and it may belong to a different geological period. The organic remains found in it, however, would place it higher rather than lower, in the scale of rocks. The large shark's tooth, No. 250, appears almost as fresh as a recent one, and probably belongs to the genus, *Carcharias*. No. 153 is a Clypeaster, five inches in diameter, mostly converted into yellowish calcareous spar. — (*Bronn's Lethæa Geognostica*, Tab. XXXVI, fig. 9.) No. 151 is a very perfect nucleus in limestone of a Cardium, or an Arca; No. 152 a similar nucleus of an Isocardia; probably the I. co., of Goldfuss, Tab. 141, fig. 2. No. 142, from the spot where St. Paul was shipwrecked, appears to be a limestone of an older date than those above described, if we may judge from its somewhat crystalline texture.

Unstratified Rocks and Volcanic Action in Syria and Palestine.

It has long been a favorite theory with many Christian writers, that the cities of Sodom and Gomorrah, Admah and Zeboim, were destroyed by a volcanic eruption; and that, indeed, the Dead Sea did not previously exist; and that formerly the river Jordan flowed into the Red Sea at Akabah. The statements of travellers, in former times especially, respecting the vicinity of the Dead Sea, have seemed in a good measure to confirm these hypotheses. The peculiar character of the waters of that sea, their entire destitution of animal life, the great depth at which that lake lies below the frowning black and naked mountains around, and the general sterility and desolation which reign there, as well as the savage character of the few wandering Bedouin Arabs who inhabit the region, all give such an impression of the penal curse which seems to rest upon it, that the minds of travellers appear to have been generally overwhelmed with awe and amazement, and rendered incapable of calm and scrutinizing observation. But within a few years past, a different set of observers have given us their reports, and none of them more trusty ones than our own countrymen, whose names have been already mentioned; and the geologist now possesses perhaps the materials for deciding some of the points above stated. The subject of volcanic action in those countries becomes, on account of its historical associations, of great interest; particularly as to the time of its occurrence.

In order to form correct opinions on these subjects, it will be necessary briefly to describe that long valley, or gulf, called *el Arabah*, extending from the Red Sea at Akabah, to the Dead Sea, and thence along the river Jordan to the mountains of Anti-Lebanon; a distance of nearly two hundred and fifty miles. Its breadth is several miles, sometimes as many as ten or twelve: but its exact depth cannot be stated, although in some parts, as along the Dead Sea, and south of it, the adjoining mountains rise above it not less than three thousand feet.

If we begin at the Red Sea at Akabah, and proceed northward through this valley, we shall find its bottom gradually rising; that is, sloping southerly for about twenty miles; and the side valleys, or Wadys, as they are termed, fall into the Arabah so as to make slightly acute angles with it on their northern sides, and obtuse angles on their southern sides: that is, they fall into the Arabah, as the branches of a river running southerly do, into its main channel. These Wadys, however, as well as the Arabah, have no streams in them except in the winter. About twenty miles north of Akabah, we reach, according to Robinson and Smith, the highest part, or watershed, of this valley between the Red Sea and the Dead Sea. Thence the slope is northerly to the latter, a distance of nearly sixty miles: and this slope is as great as it is towards the south. From these facts we might infer with confidence, that the Dead Sea must lie at a considerably lower level than the Red Sea. Barometrical observations have been made within a few years past, tending to confirm this inference. The results of different experiments with the barometer are, however, very wide apart.

Moore and Beke, in 1837, make the Dead Sea lower than the Mediterranean,	500	English feet.
Schubert, do. in 1837,	599	Paris "
Russegger and Bertou, do. in 1838,	1300	" "
Wilkie, Beadle, and Woodburn, in 1841,	1417	English feet.

The point, however, has more recently been settled by trigonomical surveys. Lieut. Symonds, of the British Royal Engineers, has in this way shown that the depression of the Dead Sea below the Mediterranean is thirteen hundred and thirty-seven feet, and that of the Sea of Tiberias eighty-four feet. (*American Biblical Repository, for July*, 1842, p. 325.) Still greater is this depression below the Red Sea; since this is said to be twenty-eight feet higher than the Mediterranean. This is a most remarkable fact, the parallel of which has not been discovered on the globe; although the Caspian Sea is said to be one hundred and eight feet below the Black Sea. As we follow the valley of the Jordan northward from its mouth, we ascend at the rate of about twenty feet in a mile to the lake of Genesareth, which is a little over sixty miles from the Dead Sea. North of this lake, the ascent of the Wady is more rapid, until it is lost among the mountains of Anti-Lebanon; though, after all, I strongly suspect the plain of Cœlo-Syria to be a continuation of the Arabah; and thus we should make its termination to be not far from the mouth of the Orontes.

I ought to have mentioned, that about ten or twelve miles south of the Dead Sea, ledges of limestone, some hundreds of feet high, curve around so as to cross the entire valley of Arabah. But a deep gorge, not less than half a mile broad, fifty miles long, and more than one hundred feet deep at its northern extremity, called Wady el Jeib, is found to cut through the limestone terrace, forming a bed for the waters of winter to descend towards the Dead Sea. I ought, also, to state, that all the lateral Wadys north of the watershed in the Arabah, tend towards the north, or in a direction opposite to those south of the watershed.

Now it is almost exclusively along the valley of the Arabah that we find the traces of ancient and recent volcanic action. Beginning at its southern extremity, we find travellers describing granite and trap rocks in the vicinity of Akabah; and Burckhardt says, that ancient volcanic craters occur in that vicinity. In going northerly, a lofty range of mountains, the mountains of ancient Edom, bounds the east side of the valley; but of their nature I know nothing till we reach Petra, where sandstone abounds; probably the new red sandstone. A little to the north, the order of strata in ascending the mountain, three thousand feet high, according to Robinson and Smith, is limestone at the base, next porphyry, forming the main body of the mountain; above this, sandstone; and at the top, limestone. Between this place and the Dead Sea, limestone is the only rock spoken of by travellers along the Wady, and it is said that the mountains all around that sea are of limestone. This is certainly the case on the west side: but those on the east side have not been so well ascertained. Irby and Mangles found fragments of granite and porphyry on the southeast shore; and Seetzen describes the mountain there as of gray sandstone. My collection is altogether wanting in specimens from the east side of the sea, except the small fragment No. 363, which seems to be siliceous slate. But I think we may safely conclude, that there does not exist on that side of the sea any decided marks of volcanic action, or they would have been noticed by such intelligent travellers as have passed over that region. Near the northwest part of the sea, however, both Mr. Hebard and Mr. Homes picked up specimens of genuine *vesicular augitic* lava, Nos. 126 and 362. The latter was obtained by Mr. Homes "from a mound once surrounded by the Dead Sea;" and I understood that gentleman to say in conversation, that this small mound was composed of similar rock. But Dr. Robinson is of opinion, that the specimens obtained by Messrs. Hebard and Homes, were mere loose fragments; and he saw no lava in place, as he passed along that side of the sea. The same is true along the Jordan, until we get as far as the Sea of Tiberias, whose shores are covered with black lava of almost every sort: Nos. 119, 120. A few miles to the northwest of that lake, and a little beyond Safed, near the village of Kadita, Mr. Hebard discovered a distinct crater, from which No. 125, whose cavities contain *hyalite*,[1] was obtained. It is between three hundred and four hundred feet in its longest diameter, and one hundred and twenty in its shortest; and about forty feet deep. (*Robinson and Smith*, vol. 3, p. 367.) Following the Jordan to its source, similar vesicular and compact lava and basalt are found, as Nos. 121 and 123, from the east side of Anti-Lebanon, will show; and I have little doubt that they may be found almost uninterruptedly through the whole extent of that chain, as far as Aleppo. Indeed, Messrs. Thomson and Beadle, in passing from Beyroot to Aleppo, found volcanic rocks in great abundance: west of Aleppo, indeed, over a space of fifty miles broad; that is, reckoning on a parallel of latitude.

On the southwest side of the Dead Sea there exists an interesting deposit of rock salt, called Kashum Usdum, from its situation near the ancient Sodom. It forms a ridge from one hundred to one hundred and fifty feet high, five miles long, covered in many places with layers of chalky limestone. This fact seems to settle its place among the formations; proving it to be connected with the cretaceous group. But if rock salt be essentially a volcanic product, as we have strong reason to believe, its position among the stratified rocks shows only how late it was protruded. The salt of Usdum, beneath the surface, has a highly crystalline structure, and is even almost limpid; as No. 423 will show. For that specimen I am indebted to Dr. Robinson; and having subjected it to chemical examination, it showed distinct traces of a sulphate, as well as of lime and magnesia; but I could not detect in it either bromine or iodine. The above ingredients exist in it in about the same proportion as in fossil rock salt generally, as I ascertained by comparative trials; and it may be regarded as a tolerably pure variety of salt. Along the western shore of the sea are several brackish springs: indeed, we know of but one of much size that is sweet, namely, that at Ain Jidy. Fragments of sulphur and nitre have also been picked up on the shore in various places.

The waters of the Dead Sea are subject to a considerable rise and fall during the year. The rains of winter and the melted snows of Anti-Lebanon produce a rise of several feet, while the long-continued heat of summer, being very intense in so deep a gulf, produces an abundant evaporation. Robinson and Smith saw decided evidence, in the drift-wood lodged along the shore, that the waters had been, during some part of the year, as many as fifteen feet higher than when they visited them. This of course produces a considerable difference in the size of the sea at different times: particularly at the south end. The valley extending southerly is for several miles very low: so that, in fact, a rise of the waters a few feet causes them to extend southerly several miles. That tract, when the waters have retired, appears like the estuary of a river, when the tide has gone out. The south end of the sea is, also, rather shallow, and there is reason to believe that a ford has existed, and perhaps does now exist, a considerable distance northerly from the end, where a remarkable peninsula extends more than half-way across it.

The very peculiar character of the Dead Sea water has long been known; and the nature of the salts, which give it so bitter and saline a taste, has been so well settled by the analysis of at least seven able chemists, that I have deemed it useless to make any trials upon it. The specimen No. 499, was probably taken not far from the mouth of the Jordan; and, therefore, has a specific gravity of only 1170; whereas the specimen analyzed by Gay Lussac had a specific gravity of 1228. The chloride of magnesium forms the predominant ingredient in this water, and hence its bitter taste. But there is a good deal of discrepancy in the per centage of the different salts, as obtained by different analysts. This may probably be explained without imputing it to errors of analysis. For if the specimen examined were taken near the mouth of a fresh-water stream, its ingredients would obviously be different from one taken at the mouth of a rill from Usdum, or one of the brackish springs along the shore. Every where, however, it contains salts enough to be fatal to animal life. Prof. Gmelin detected bromine in the specimen which he analyzed. It ought, also, to be stated here, that although the waters of the Jordan are regarded as sweet, Dr. Marcet found in them the same ingredients as in the Dead Sea, and in about the same proportion. And when we examine the hot springs on the west shore of lake Tiberias, I think we find the origin of this saline impregnation. For their taste is excessively salt and bitter, and they make deposits as they run to the lake. It is stated by the traveller Monro, that the water of these springs, or rather their deposit, was analyzed by Dr. Turner, and found to "consist chiefly of carbonate of lime with a very small proportion of muriatic salts, differing in no respect from that of the Dead Sea." The Dead Sea, however, contains no carbonate of lime; and this statement seems quite defective. Mr. Hebard found the temperature of these springs to be one hundred and forty-four degrees, Fahr. They issue from the dark bituminous limestone already described as occurring on the shore of the Dead Sea.

Dr. Marcet does not appear to have made a quantitative analysis of the waters of the Jordan. Probably it was only a qualitative analysis, and he judged of the amount of the ingredients by the eye. The following experiment of a similar kind occurred to me, which I performed. I took some of the water of the Dead Sea, No. 499, and diluted it very much with distilled water, and then put some of it in test tubes, as I did also some of the water of the Jordan, No. 554; placing the tubes side by side. I then applied chloride of barium, nitrate of silver, oxalate of ammonia, and ammoniaco-phosphate of soda, and noticed the amount of the precipitate in each pair of tubes, one of which contained the water of the Jordan and the other that of the Dead Sea diluted. The sulphates were evidently in the greatest quantity in the water of the Jordan: indeed, the test scarcely showed any in that of the Dead Sea. The chlorides were about the same in both, as was also the lime: but the magnesia was most abundant in the Dead Sea water. While this experiment, therefore, confirms the statement of Dr. Marcet, that the same ingredients are found in both these waters, it makes it doubtful whether they exist in the same proportion. But the difference admits of explanation consistently with the views that have been expressed, partly by supposing a decomposition of the sulphates of the Jordan after they are carried into the Dead Sea, and partly by the influence of the mineral springs and those from Usdum, along the shores of the sea. The waters of the Jordan, although I could not perceive in them any brackish taste, obviously contain much more saline ingredients than is usual in river water: but I have not enough of No. 499 to enable me to make a quantitative analysis.

It has long been a prevalent opinion among authors, that the Dead Sea furnishes large quantities of asphaltum. But the researches of Robinson and Smith render it probable, that whatever might have been the case in ancient times, it is rather a rare occurrence to meet with this substance in much quantity in modern days; although small fragments may be occasionally picked up along the shore. Mr. Smith's perfect knowledge of the Arabic language, gave him facilities for obtaining information among the people, possessed, I believe, by scarcely any preceding traveller except Burckhardt. The Arabs informed him that it was only after an earthquake, that large masses of bitumen were found floating in the waters. After the earthquake of 1834, a large quantity drifted ashore, near the south end of the sea; of which the Arabs brought about six thousand pounds to market. A mass like an island, or a house, rose to the surface after the earthquake of 1837; of which the inhabitants sold to the amount of about three thousand dollars. These were the only instances known to the Sheikh of the Jehâlîn, resident in that vicinity, a man fifty years old: nor did his fathers hand down to him the tradition of any other mass having been found in the sea. There is, indeed, a prevailing tradition among the Arabs, that the asphaltum exudes from the rocks on the eastern shore of the sea: but there is good reason to doubt whether such be the fact.

The character of the valley of the Jordan is an important element in our reasonings concerning volcanic action in Wady Arabah. This valley is broader in many parts than the Dead Sea; in some places as much as ten or twelve miles. It is terraced, as we find almost all the valleys in the mountainous parts of our country. In all the upper part of the valley, the terraces are two on each side of the river; that is, we ascend the immediate banks of the river and come upon the first terrace, which is frequently overflowed and covered with vegetation. We ascend a second terrace, which brings us upon a plain fifty or sixty feet above the river, and exceedingly barren. Towards the mouth of the river, is a third terrace, a few feet lower than the first above described; and both these lower terraces are covered by vegetation.

Such are the leading facts respecting the topography and geology of the Arabah. Now for the inferences.

1. There is every reason to believe that a fault runs through the entire length of this valley, from Akabah to Anti-Lebanon; and probably to the Mediterranean near Aleppo. This was the opinion of Von Buch, in reply to the inquiries of Dr. Robinson, and it will doubtless be adopted by every geologist. Along such a fault we should expect that volcanic agency would be active at various epochs. And such appears to have been the case.

2. There is no evidence that any volcanic eruption has occurred along the Arabah, or in any part of Palestine or Syria, within historic times. Lava appears to have been ejected most recently,

a little west of the Sea of Tiberias. But had the eruption taken place since the country was inhabited, some tradition of it must have been transmitted in histories that date so far back as the sacred books. The epoch of the eruption from the crater near Safed, was probably embraced in the period of extinct volcanos in other countries.

3. There is no evidence that any proper volcanic eruption has ever taken place in, or around, the Dead Sea. The mountain of rock salt at the southern extremity was probably the result of volcanic action, at least in part; but it could not have been produced by a common eruption: and even if the specimens of lava, Nos. 126 and 362, were from a rock in place, the quantity is so small as to indicate a very slight eruption. Craters and lava may yet be found in the mountains east of the sea; but if the sea itself formed the crater, it is incredible that the lava should not be found covering the western shore.

4. The present levels of the surface around the Dead Sea, and the contour of the hills and valleys generally throughout Palestine, cannot have been essentially altered since the existence of man upon the globe. Two facts, which I have stated, seem to me to establish this point beyond all reasonable doubt. The first is the character of the valley of Arabah, south of the Dead Sea. For about sixty miles it descends towards that sea; while the Wadys, that enter it from either side, trend northerly, and they are worn as deep as valleys in other parts of the world that unite to form larger valleys and streams. Now we have abundant evidence to show, that such valleys, in regions not volcanic, have not been essentially altered, except in some limited spots, within historic times. The Wady el Jeib, which is a deep gorge through the limestone cliffs towards the Dead Sea, is wider, and nearly as deep, and very much longer, than the famous gulf between lakes Erie and Ontario: and if the latter has resulted from the slow operation of the Niagara river, and must have required an immense period for its accomplishment, (and who that has examined the spot will doubt this ?) the former, also, may probably have been the result of the slower action of the winter torrents that flow through the Arabah. Nor would it be strange, if those who quote the gorge of the

Niagara in proof of the immense antiquity of the present configuration of the globe in that region, should draw a similar argument from the Wady el Jeib respecting the region around the Dead Sea.

The second argument in favor of the general position, that the region around the Dead Sea has not been essentially changed within historic times, is derived from the character of the valley of the Jordan. It is terraced almost exactly like the valleys in primary regions far removed from volcanic action. And the height of the upper terrace is about the same as on rivers of the same size in New England. Now, although there is not an entire agreement among geologists as to the mode in which this peculiar arrangement of the sides of the valley was produced, yet all agree that it must have been the result of a very slow action, and that the waters of the river must have been concerned in removing the matter which once filled the valley as high as the upper terrace. Nor do we find that these terraced valleys have been essentially changed during the memory of man; that is, the terraces remain very much as they were in the earliest periods of human history. No reason, therefore, can be given, why the valley of the Jordan should be an exception. But had the level of the country around the Dead Sea been essentially elevated or depressed, the effect must have been, either to produce a permanent inundation of the valley of the Jordan, in case of a rise of the bed of the sea; or a sinking down of the bed of the river, in case of the depression of the sea, so as to make its banks very high. Neither of these effects have taken place in that valley (with a slight exception, to be noticed below), more than in valleys in other parts of the world; and, therefore, we may infer, that no extensive change of level has occurred there within historic times.

4. Hence the theory recently proposed with much confidence, that, before the catastrophe of Sodom and Gomorrah, the river Jordan flowed through the whole of Wady Arabah, and emptied into the Red Sea at Akabah, is wholly untenable.

5. Hence, too, the supposition that the Dead Sea did not exist previous to that event, is equally without foundation.

6. Hence, likewise, the hypothesis so long in vogue, that

those cities were destroyed by a common volcanic eruption, must be given up.

7. But seventhly, there is reason to believe that, from time to time, the level of the Dead Sea has been considerably depressed by volcanic agency. In order that the sand of the upper terrace of the valley of the Jordan should be deposited, the waters of that river must have flowed over it: in other words, the Dead Sea must have once extended northerly far enough to cover that valley; for there is no barrier at the mouth of the Jordan, which might formerly have kept its waters at a higher level than those of the Dead Sea. To raise the sea above the highest terraces at the mouth of the Jordan, would not require an elevation above its present level of more than sixty feet; but as the slope of the valley southerly from the Sea of Tiberias, is, upon an average, twenty feet in the mile, it would require a rise of several hundred feet to throw back the waters over the whole of the broader part of the valley. But if we admit that the waters of the Dead Sea have suffered so much depression in comparatively recent times, still, the greater part of the work must have been accomplished previous to the existence of man upon the globe. For, as above remarked, the terraces on other rivers, and therefore those upon the Jordan, have not been very much changed since the earliest historic times; and the terraces upon the latter stream could not have been formed, until the Dead Sea had sunk so far as to leave dry the space now occupied by the terraces. Still, I think there is good reason to believe that the bottom of the Dead Sea, certainly of its southern part, may have sunk a few feet as late as the time of the destruction of the cities of the plain. That Sodom and Gomorrah were situated at the southern part of the Dead Sea, seems highly probable; because many of the ancient writers located Zoar, which was near to Sodom, on the southeast side of the present sea. But at present there is not room enough for such cities on the borders of the sea; and the soil in general is extremely sterile. Further, the scriptures speak of the vale of Siddim, *which is* not on the borders of, *but which is the salt sea*: that is, it was sea when the event alluded to (a battle, before the destruction of Sodom) was described, but dry land when it took place. An-

other fact mentioned by Robinson and Smith, renders a recent sinking of the Dead Sea somewhat probable. Towards the mouth of the Jordan there are three banks, or terraces, on each side of the river: but higher up the stream, there are only two. The lowest terrace is only a few feet below the second. Now suppose the plain at the south end of the sea to have sunk a few feet, so that the waters flowed over it: the effect would be to sink the whole sea; especially if the depression extended, as it probably would, to the entire bottom of the sea. There is another circumstance, which not only favors the idea of such a depression of the surface, and an overflow of the waters, but gives a probability to the opinion that the southern portion of the Dead Sea is the site of Sodom. It is stated in scripture, that the vale of Siddim, in which the cities of the plain were situated, was full of slime-pits; that is, *wells or fountains of asphaltum;* the same word being used as is employed in describing Babylon, whose walls we know were cemented by bitumen. No such wells occur, as we know of, any where around the Dead Sea: but, as we have seen, large masses of asphaltum have risen to the surface sometimes, as the effect of earthquakes, near the south end of that sea; and only at the south end. If springs of asphaltum exist beneath the waters, this would be a legitimate effect of the gradual accumulation of fluid bitumen, and its consolidation into asphaltum. As it is a good deal lighter than water, a violent agitation of the surface would detach it and cause it to ascend.

Now it is well known, that such effects as have been described, might be the result of volcanic agency, where there was no eruption of lava. The sudden subsidence of towns and cities on the sea-coast, from a few feet to several hundred, has been a not uncommon occurrence; as of Port Royal in Jamaica, in 1692; of Lisbon, in 1755; of Euphemia in Calabria, in 1638; and of Sindrea on the Indus, in 1819. In the latter case the sea rushed in and covered a space of two thousand square miles. Through the fissures produced by the earthquake, steam, hot water, mud, sulphur, petroleum, flames, and suffocating vapors, have several times been known to issue. We have here, then, all the ingredients and all the agency necessary to produce the destruction of the cities of the plain, according to the scriptural account, which says, that *the Lord rained upon Sodom and upon Gomorrah brimstone and fire from the Lord out of heaven.* It may be, too, that the flames, or rather the burning sulphur, would set on fire large quantities of bitumen, which had accumulated at the fountains, or pits, and thus increase and prolong the conflagration, and produce vast quantities of smoke, so as to make it not strange, that, as Abraham looked towards Sodom next morning, *the smoke of the country went up as the smoke of a furnace.* Indeed, one is reminded, by this description, of the account Kircher has left us of the destruction of Euphemia, by a similar agency. " After some time," says he, " the violent paroxysm (of the earthquake) ceasing, I stood up, and turning my eyes, to look for Euphemia, saw only a frightful black cloud. We waited till it had passed away, when nothing but a dismal and putrid lake was to be seen, where the city once stood." The sinking down of the land and the rushing in of the waters, frequently does not take place till towards the close of the earthquake, so that, in this case, there might have been time for the fire to consume the cities before the water overflowed them. It is also not at all improbable, that the ridge of rock salt, called Usdum, might at the same time have been protruded further than before, so as to become visible. In the earthquake of Cutch, a long elevated mound was thrown up, which the natives called *Ulla Bund* or the *Mound of God.* With still more propriety might Usdum receive this appellation.

I cannot adopt the opinion suggested by Robinson and Smith, Michaelis and Busching, that the combustion of the bitumen was the principal cause of the sinking of the surface below the level of the Dead Sea. For first, it would require a quantity much greater beneath the earth's surface than we have any example of; and secondly, if it were beneath the soil, as it must be to render the surface habitable, it would burn but slowly, giving sufficient time for the inhabitants to escape, which does not seem to have been the case.

8. Eighthly, if these suggestions be admitted, we can easily see how it was, that the plain, on which these cities stood, when Lot chose it for his dwelling-place, and which was well watered

and fertile, so as to be called the garden of the Lord, has, since the destruction of Sodom and Gomorrah, been one of the most desolate spots on earth. It is well known that common salt, when mixed in proper quantity with the soil, very much increases the fertility; but, if applied in too large proportion, it is eminently fatal to vegetation. If the Dead Sea existed before the catastrophe of Sodom, it would impart sufficient saltness to the surrounding region to render it very fertile. But if its limits, after that event, were much enlarged, and especially if Usdum was protruded to the surface, so as to impart saltness to most of the fountains, the excess of salt would produce the sterility which now reigns there. It so happens that we have at least three good illustrations of these views, on the western shore of the Dead Sea. At Ain Jidy is a copious fountain of fresh water, and along the banks of the stream issuing from it, is the most luxuriant growth of vegetables which Dr. Robinson ever saw. The same is true around Jericho, although the surrounding country is very sterile. A similar fertility exists along the mouths of the streams that empty into the sea on its southeast side, near the site of the ancient cities. I shall hereafter quote another example from the vicinity of a similar salt lake in Persia. In short, I do not doubt, that if a sufficient quantity of fresh-water streams were now to flow into the Dead Sea, unless they passed across Usdum itself, its shores would again become as luxuriant as Egypt.

9. Finally, we see, in the facts detailed, the principal origin of the salts contained in the Dead Sea. It is not Usdum, as some have supposed; for then common salt should be the chief ingredient. Yet doubtless Usdum increases the quantity of that substance, and so do the brackish springs along the shore have some effect. But the principal source of its peculiar qualities, I doubt not, are the hot springs on the west shore of the Sea of Tiberias, as I have already endeavored to show. These waters flow into the sea, and are evaporated by the great heat which prevails there, and thus the solution becomes condensed almost to saturation. It is seldom, it seems to me, that we can trace effects more satisfactorily to their source, than in this instance. And yet I do not recollect to have seen these springs mentioned as the source of the

impregnation of the Dead Sea, though Dr. Marcet does suggest that it may be derived from the waters of the Jordan.

In the remarks which I have made concerning the destruction of the cities of the plain, I wish not to be understood as denying the miraculous character of that catastrophe. I have inquired simply what was the agency employed by the Deity to accomplish this purpose. We know that He does not unnecessarily contravene the laws of nature, but employs natural operations, even for the accomplishment of what we might call a miracle. As to the destruction of these cities, the sacred narrative does not decide whether it was done miraculously, or otherwise. It does, indeed, impute it to the direct agency of God; but this is the manner in which every natural event is spoken of in the Bible. Hence we are at liberty to regard that catastrophe as natural or miraculous, according as we can or cannot explain it by natural operations.

There are a few facts to be added respecting the subject of drift in the countries that have now been under review; but these may with more convenience be connected with similar phenomena in countries further north and east; and therefore I shall defer them to another place.

I will close my remarks concerning Syria and Palestine, by a few statements respecting a mineral water of great historical interest, under the walls of Jerusalem, on its southeast side. It is the pool of Siloam. By the recent researches of Robinson and Smith, it is made certain that this fountain derives its waters from the fountain of the Virgin, several hundred feet higher up the valley; and there is good reason for believing that the latter is supplied, through an artificial excavation, from a well, some eighty feet deep, beneath the site of the ancient Temple of Solomon; and there is some reason to believe, that the waters of this well are derived from the fountain of Gihon, beyond the western wall of the city; and are conveyed to the temple (now the mosque of Omar) by a deep excavation. The taste of the water, which Dr. Robinson describes as "sweetish and very slightly brackish," is the same in the well and in the fountain of the Virgin, as in the pool of Siloam. Probably, also, Siloam is identical with the King's Pool, and the Pool of Bethesda, mentioned in scripture.

I am indebted for the specimen of this water, No. 555, to the Principal of the Mount Holyoke Female Seminary, who received it from Rev. Mr. Sherman, American missionary at Jerusalem.

The taste of this specimen is decidedly acid, somewhat like weak vinegar. On mixing it with a delicate purple infusion of the blue petals of a flower, it changed the color to red; and this remained unchanged for several days, precisely like a test experiment with nitric acid. It is impossible, therefore, that the acid should be the carbonic. It may, indeed, be a metallic salt, and not a free acid, which gives it its acid taste. But so decidedly acid is the taste, that I could not but suspect the specimen may have been accidentally put into a vessel containing an acid; and yet this is not probable. I regret that the small quantity of water in my possession has not allowed me to do any thing more towards its analysis, than to make a few tentative processes; and even those could not be repeated. I should not state them at all, so imperfect are they, had I ever met with any account of the ingredients in this very interesting water. I operated upon only fifty grains of the water with each reagent, and obtained the following results by a single trial.

In five hundred grains I find,

Sulphuric acid, ...	0.78 grains.
Chlorine, ...	0.49 "
Magnesia, ...	0.04 "
Lime, a very distinct trace.	

The ferro-cyanuret of potassium gave a green color to the water, and, in the course of a few hours, a blue precipitate, whence I infer, that the water is ferruginous and alkaline. (*Traité de Chimie par Berzelius*, *Tome Huitième*, p. 85. *Bruxelles*, 1840.)

Though little dependence can be placed upon the preceding results as to the proportion of the ingredients, yet they indicate, clearly enough, that Siloam must be a rather powerful mineral water. Indeed, Dr. Robinson states, that when the pool is low it is unfit for common purposes. It is much to be desired that it should receive a thorough analysis.

The second division of countries to which I wish to call the attention of the Association, embraces a few islands in the Grecian Archipelago, and some places in the western part of Asia Minor. I begin with the islands; from which nearly all my specimens were sent by Rev. Dr. Robertson and Mr. Van Lennep.

No. 369 is granite, or more probably granitic gneiss, from the summit of mount Cythnus, on the island of Delos; showing us the probable character of the nucleus of the island. But No. 191, which is the half of a stalactite, five and a half inches in diameter, sent by Mr. Paspati, indicates the presence also of limestone.

No. 384 is highly crystalline limestone from the island of Tenos; appearing precisely like highly porous lava. But the cavities are the work of some lithodomous animal; no relic of which, however, remains.

No. 378 is an epidote from the same island, and is said to be abundant there.

The specimen of red jasper, No. 393, is from the island of Egina, and occurs there abundantly in rolled nodules; and it is said, also, in limestone.

The red limestone and calcareous spar, Nos. 318 and 319, are the only specimens sent from the island of Samos.

The delicate chalcedony, shown in Nos. 335, 336, and the jasper, No. 338, are from Cyprus. The sulphate of iron, No. 300, is from the same island, and is said to be a natural product; but I suspect a mistake here. No. 635 is slaty gypsum, used for floors in Cyprus; but Mr. Van Lennep, who sent it, does not say that it is found in the island.

The principal summits in the island of Syra, according to Dr. Robertson, consist of a yellowish compact limestone, such as Nos. 381, 382 exhibit. He says, that the rocks there are mostly primary, consisting mainly of mica slate, talcose slate, and hornblende slate, as shown by Nos. 372, 373, 377. The two first specimens have *pyrope* associated with them. Beautiful *actynolite*, (No. 375) is also abundant there; and the hornblende is sometimes of a delicate blue color, (No. 376,) if the specimen be indeed hornblende. The talcose slate, No. 377, shows the talc in a somewhat indurated state, such as is common in the talcose slates formerly called transition. And the compact character of the limestone would lead to the conclusion that that rock is of a similar age. The hornblende slate, however, appears to be the oldest variety of that rock. The drusy quartz, No. 392, passing into chalcedony, or even hyalite, is said to be abundant in the mica slate of the island. The iron sand, No. 397, is cemented into a rock, and the deposit increases daily on the seashore. It appears to be a mixture of fine clay and iron, and the latter probably performs the part of a cement.

The specimens sent me by Mr. Van Lennep from the island of Rhodes, are very interesting. They consist of tertiary fossils. Says Mr. Van Lennep, "I visited Rhodes lately, and found the northern extremity of the island to contain an inestimable mine of fossil shells: some in solid rock, others in a sandy deposit, which disintegrates by the action of the atmosphere." This sand (No. 633) is made up of coarse grains of different minerals, fragments of shells, and many entire valves of shells. It has a greenish aspect, and considerably resembles green sand. The following genera of fossils exist in the collection. The species are all very different from any with which I am acquainted, and the probability is that many of them are new: but I have not the means of determining this point; and therefore leave them unnamed, with a few exceptions.

No. 621. Clypeaster, *Lam.* Species not figured in Goldfuss's Petrefacta Germaniæ.
No. 615. Pectunculus pulvinatus ? *Lamk.* Goldfuss's Petrefacta, Tab. XXXVI. fig. 5.
No. 616. Turbinolia, approaching T. cuneata of Goldfuss ; Tab. XV. fig. 9, but different.
No. 617. Natica.
No. 618. Pecten, not figured by Goldfuss.
No. 619. Dentalium.
No. 620. Pyrula.
No. 622. Turbo.
No. 623. Lutraria : Length one inch and three fourths : breadth, three inches and three fourths.
No. 624. Cerithium.
No. 625. "
No. 626. Trochus.
No. 628. Operculum of a univalve.
No. 629. Fragments of Pecten, &c. in chalky limestone.
No. 631. Turritella with Serpula.
No. 632. Serpula.
No. 634. Pectunculus polyodonta, Bronn. This large species corresponds very closely to the figure of P. polyodonta in Goldfuss's Petrefacta, Tab. CXXVI. fig. 6. It is said by that author to abound *ubicunque, in stratis marinis superioribus Germaniæ.*

We learn from Dr. Buckland, in his Anniversary Address before the London Geological Society in 1841, that most of the island of Rhodes is composed of chalk, rising in mount Atairo, to the height of four thousand feet. The chalk is partially covered by tertiary strata, from which Mr. Van Lennep's specimens were doubtless obtained.

In passing to the Asiatic continent, the region around Smyrna is the first to which I would direct the attention. This region has been described, I presume, with minuteness and accuracy by Messrs. Hamilton and Strickland, before the London Geological Society: but I have not access to their papers, or even to an abstract of them, and, therefore, I have thought it best to state the few facts within my possession; thinking it possible that some of them, obtained through Rev. H. J. Van Lennep, who is a native of Smyrna, may not be embraced in those papers.

" The country for some distance around Smyrna," says Mr. Van Lennep, " may be described, geologically, under three principal divisions. The first embraces the wide alluvial plains, which contain the rivers, and whose soil, exceedingly rich, is planted with grain or vineyards, and studded with villages, peeping at intervals through the thick olive and cypress groves. These plains extend in some directions eight or nine hours; but in others they are narrow along the seashore, and are shut in by mountains. The second division embraces various formations of stratified rocks, mostly limestone. These usually rise into hills, or mountains, generally very abrupt. One region is but a collection of high hills, sharply pointed at the top, and inclining to conical, as far as their chain-like form allows. The vegetation is quite rich on these elevations, and the olive grows wild there. The third division is volcanic, embracing many interesting rocks. A short distance from the city stands an old crater, which some have thought may have been active within historic times, though not mentioned by any author. I am more inclined to believe it one of the many which were in action before the existence of our race, and which contributed to give the earth's surface its present shape. Another fact has still more attracted my attention. The city rests in part upon a rock strongly resembling porphyritic greenstone, but distinctly stratified. In one spot I found the layers radiating from one point, and gradually assuming the general direction.

This rock is much harder than the other parts of the hill, so as to rise up above the general surface. I cannot doubt the action of fire; and yet I know not of any stratified rock of igneous origin. Much of the volcanic rock is trap, and some of it porphyry."

(Specimen No. 346, from the citadel of Smyrna, although not well characterized, appears, as Mr. Van Lennep suggests, to be porphyritic greenstone, or basalt. The division of this rock into layers, which he describes, is probably an example of pseudo-stratification; the result of concretionary structure on a large scale; an occurrence somewhat common in trap rocks.)

"Hot springs are pretty common here, of various temperatures. One of these fills a small lake, a mile from the city, which is still called the *bath of Diana.* I visited another not long ago, situated not far from Ephesus, near the sea-coast, and in sight of Samos. The ancient bathing establishment there, is still used, and the water, which contains much salt and iron, is so hot, as scarcely to admit the dipping of the hand into it. I took a bath in it, however, about noon, when the sun must have raised the thermometer to one hundred and twenty or one hundred and thirty degrees, and being necessarily exposed to its rays for several hours, I bore it much better for my scalding bath. The water flows into a plain, traversed by a small stream, and a salt marsh is produced of high rank grass, the resort of hyænas, whose growl is heard at night, as well as in the ruins of a Christian church."

The specimens sent me by Mr. Van Lennep belong chiefly to the igneous rocks. No. 345 is compact basalt, or greenstone, forming hills around Smyrna, near the sea. No. 344 is trap, with olivine, or epidote, from Cordellianæ, not far distant from the city. At Sedicui, a small village six miles from Smyrna, the trap contains numerous veins, or perhaps one very large vein, of chalcedony. (Nos. 342, 636,) connected probably with the trap in that place, is a mass of serpentine, containing bronzite, asbestus, and probably the variety of dolomite called miascite. (Nos. 347 to 352.) About two miles from Smyrna, occurs the brown pitchstone, No. 353. Brown and white opal (Nos. 354, 355) is found at Boujah, five miles southeast from the city. From the shores of the bay of Smyrna, Mr. Homes obtained the specimens Nos.

356, 357, 358, which appear to be trachytic lava and trachytic conglomerate. The trachyte occurs also at Sedicui. (Nos. 359, 360.)

The specimens of stratified rocks sent me from the vicinity of Smyrna, will not enable me to throw much light upon that part of its geology. No. 327 is clay slate. No. 326, a sort of bastard mica slate, or perhaps graywacke slate, of which No. 325 is a more distinct example. No. 328 appears as if it might be a graywacke sandstone. But I suspect limestone to be the predominant rock. Sometimes it is compact, (No. 305,) like the limestones already described from Syria and Palestine. Sometimes (Nos. 303, 304) brecciated; portions of it, usually in irregular veins, being red, from the abundance of peroxide of iron. This rock is used at Broosa as marble, and occurs on mount Olympus, near that place (Nos. 166, 167, 252); also in the island of Rhodes. (No. 42.) Some varieties of it, when weathered, have a dirty appearance. (Nos. 309, 310, 313, 314.) In one instance (No. 324 from Sedicui) we find limestone of a gray color, connected with clay slate; and the probability is, that much of it may be of the same age as that rock. In none of the specimens do I discover any trace of organic remains. The brecciated limestone, No. 308, from Sedicui, has an aspect somewhat chalky; but it is made up of hard compact fragments. Nos, 311, 312, from the same place, appear to be deposits from water, probably of comparatively recent date. No. 311, especially, shows in its delicate stratified or laminated arrangement, the marks of deposition; although it is considerably crystalline. As we might expect from the facts already stated respecting the warm springs near Smyrna, the waters generally of the springs there, deposit large quantities of carbonate of lime. No. 320 is a curious example. It is the half of an earthen-ware aqueduct, five inches in diameter, entirely filled with these deposits. Several layers of crystalline carbonate of lime appear to have been formed at first in the lower part of the pipe, and then small roots nearly filled up the passage, around which the calcareous matter accumulated, so that it exhibits precisely the appearance of a mass of petrified worms. But some of the fibres still remain. Were these all gone, the specimen might not improbably be supposed to be the relics of some animals allied to the encrinites. So rapid does this deposition take place, that pipes, such as the above, are sometimes filled in a few years. On this account they are often made more than a foot in diameter.

No. 322, is a beautiful example of that pulverulent variety of carbonate of lime, called *agaric mineral*, from a cavern near Smyrna.*

The region around the city of Broosa, in the vicinity of Mount Olympus, next claims our attention. Most of my specimens from that place were sent by Mr. Schneider; though some have been added by Mr. Homes and Mr. Van Lennep.

Hot springs are very abundant at the foot of Olympus, not far from the city. The consequence is, that tufaceous deposits are common. They are mostly calcareous, though No. 294, from the foot of Olympus, is siliceous, and was probably an aqueous deposit. Baked clay is used in the city for aqueducts, as at Smyrna, and they soon become filled with calcareous matter. "In the box," says Mr. Schneider, "you will find a specimen (Nos. 172, 173) of the earthen aqueducts of Broosa, filled up, or partly filled, by the sediment of the water. Where these pipes are in a level position, in three or four years they are completely filled. When they lie more inclined, or stand upright, it requires a longer time. The elevated platform on which the old part of the city of Broosa stands, was probably gradually formed by the numerous fountains gushing from the foot of the mountains, and leaving this deposit. On examination it is found, that the rock beneath the city, and the substance in the pipes, are of the same nature."

Nos. 187, 188, are specimens of the common rock at Broosa, and are a tufaceous, though hard and nearly compact limestone. No. 155, which is also said to be the common rock, is decided tufa. Nos. 194, 323, are calcareous tufa, broken from the curb of

* Since the preparation of the text, I have seen, in Dr. Buckland's Anniversary Address before the London Geological Society in 1841, an abstract of a paper by Mr. W. Hamilton, read before that Society, on the Geology of Smyrna and vicinity. The rocks which he describes, correspond essentially to those mentioned in the text. Mr. Strickland describes a cretaceous limestone near Smyrna with hippurites. (*Address*, p. 42.)

one of the hot springs at Broosa, used for supplying warm baths. On the label accompanying the specimens, Mr. Schneider remarks, that "the spring gushes hot from the foot of the mountain, and warms the bath sufficiently without artificial heat. At the orifice it is hot enough to boil an egg (not very hard) in five minutes. The bath is called Kükürtlü, or sulphureous bath, because its waters are strongly impregnated with sulphureted hydrogen. When a piece of the earth is broken off, the vacancy is soon filled up. Very near this spring are two others, whose waters are materially different from that which supplies Kükürtlü. I intended to have bottled some of these waters and sent them to you, that you might analyze them if you wished; but forgot it till too late. Some travellers have attempted to perform this work; but I fear it has not been done well."

No. 260 is a deposit of some interest from one of these springs. Its lower part is calcareous tufa, more crystalline than usual. Upon this is a deposit, nearly an inch thick, highly porous and somewhat crystalline, which, on boiling fifteen minutes, with twice its weight of carbonate of soda, was converted into carbonate of lime; from whence I infer the deposit to be sulphate of lime. Upon the sulphate of lime is a slight incrustation of sulphur, which Mr. Schneider says was originally "a crop of beautiful sulphur crystals."

No. 646 is calcareous tufa from the Castle Hill of Broosa, which is penetrated by cavities having the form of vegetables, around which the tufa was deposited.

Other varieties of limestone occur in the vicinity of Broosa; one of which, the brecciated, with red veins, has been already described (No. 252), as found near the foot of Olympus. At seven or eight miles distance from the city, is a mountain, where there exists the compact limestone, No. 261. In ascending Olympus different limestones occur; and at the height of six hundred feet, are several varieties of rock, (Nos. 159 to 163,) which, with some hesitation, I refer to sandstone and conglomerate. They are quarried for millstones, and Nos. 159, 160, 163, appear to be a fine-grained, highly siliceous sandstone: yet it is possible that they may be a quartzose variety of gneiss, in which the feldspar has been more or less decomposed. An example of this sort I have described as occurring in Berkshire county in Massachusetts, in my Final Report on the geology of that State. In Massachusetts, also, this rock is used for millstones. At Broosa the rock is sometimes highly cavernous, from the existence of small segregated veins, between which some highly ferruginous substance has nearly disappeared. The cells thus produced, take the form of a cube or a parallelopiped; and, in some of the specimens, the whole mass appears as if it might be a vegetable relic, (Nos. 160, 163.) A similar appearance exists in some varieties of the limestone found near the foot of Olympus. (No. 166, from ruins in Broosa.) But I doubt, in either case, whether genuine vegetable remains exist. This sandstone, or perhaps metamorphic gneiss, passes sometimes into a decided conglomerate; as Nos. 161, 162. The imbedded pebbles are quartz, hornstone, and jasper. In the same rock occur fine tabular crystals of sulphate of baryta, with dihedral summits, and of a color inclining to wine yellow, (No. 165.) A quartzose conglomerate exists, also, in connection with the pseudo-burrhstone in Massachusetts, above alluded to; and upon the whole the resemblance between the two cases is rather strong.

The chain of Olympus reaches its greatest height, of nine thousand one hundred feet, not far from Broosa. "This chain," says Mr. Van Lennep, "advances from the eastward, rises to its loftiest summit, and stops suddenly short. The earlier rocks it has displaced form a gradual slope, which extend a mile or two beyond Broosa westward." (Mr. Van Lennep here introduces a section, showing the rocks on this slope in the following order: first, primary or early secondary limestone: secondly, calcareous tufa with vegetable impressions: thirdly, limestone and argillaceous slate: fourthly, rocks of igneous origin: fifthly, early secondary limestone and argillaceous slate: sixthly, limestone conglomerate. He then proceeds to notice the rocks north of Olympus.) "The chain runs east and west. Immediately north of it, lie generally rich alluvial plains. These are sometimes interrupted by limestone hills. Beyond the plains are also hills of the same limestone. Further on towards Ghunlik, the ancient

Rios, are hills of argillaceous slate, containing much limestone, which make an excellent soil for wheat. Towards the lake of Nice, there are hills of porphyritic trap with some columnar formations."

Messrs. Hebard, Van Lennep, and Schneider, all agree, that the principal body of Olympus is gneiss, with occasional beds of crystalline limestone. The specimens which they have sent, fully sustain this opinion. Nos. 271 to 278 are distinct gneiss: No. 279 is gneiss passing into hornblende slate, and Nos. 280 to 284 are hornblende slate. Nos. 285 to 288 are varieties of mica slate from near the base of the mountain. The limpid quartz, No. 289, and the quartz rock, No. 290, are from the same place. The massive garnet, No. 291, is from near the summit of the mountain, where it is said to be very abundant. The limestone associated with the above rocks is usually white and granular, as shown in Nos. 156, 157, 158, and 246. The latter is from the summit, and resembles dolomite. But on analysis I find the following to be its composition.

Earthy residuum, ...	0.67
Carbonate of lime, ...	99.33
	100.

This limestone is highly fetid, a fact which I have noticed often in some of the highly crystalline limestones associated with gneiss in this country. No. 243 is columnar calcareous spar, obtained by Mr. Hebard from the top of Olympus.

Towards the foot of Olympus is a deep ravine in the compact limestone, where extensive tufaceous deposits have taken place, and large quantities of stalactites, stalagmites, and especially crystals of calcareous spar, are seen lining the mural faces of the rock and the numerous small caverns existing there. Nos. 239, 242, and 641, are examples of the stalactites, and No. 240 is a singular and unusual form of stalagmitic deposit, which I have sometimes seen going on in water at the bottom of a limestone cavern. Nos. 230 to 238, and 239, 240, are examples of the varieties of crystallized calcareous spar from this spot. The crystals, so far as my specimens show, all assume the form of extremely acute rhomboids. Their acute trihedral summits are sometimes replaced by a much more obtuse trihedral summit, forming a doubly trihedral termination. But it is difficult to give a definite idea of these crystals without figures. Those with simple trihedral summits correspond nearly to Figs. 101, 106, and 108, of Shepard's Mineralogy, Vol. I. p. 99, 100. But I have found it impossible to measure the obliquity of the rhomboid, because only the terminating pyramid projects from the surface.

No. 241 is a small stalactite formed at Broosa by water dripping from an aqueduct. It is scarcely at all crystalline, but consists of thin successive cylinders of soft limestone enveloping one another, and apparently cohering so little that one might be slipped out of the other, were they not somewhat irregular.

Nos. 176, 177, 184, and 185, were obtained by Messrs. Schneider and Powers, on an excursion from Broosa to Kutaieh. They appear to be metamorphic slates, and indicate the powerful action of heat. No. 171 appears, also, to be metamorphic, and contains a large per centum of red oxide of iron. No. 170 is a beautiful mixture of red and white opal, from the plain of Kutaieh, near a ridge of the Taurus.

Nos. 178 and 295 are vesicular lava from the *Katakekaumene*, or *Burnt District* of the Greeks, described by Strabo. It lies east of Smyrna, near the ancient Philadelphia. Mr. Schneider says, "these black stones extend over a distance of twenty or thirty miles, and the whole has the appearance of a stream of lava, not very wide, suddenly cooled." No. 362 is compact lava from the same district, sent me by Mr. Homes.*

In 1841 Mr. Van Lennep took an excursion by land through a part of Asia Minor, thence across the Sea of Marmora into Roumelia, as far, I believe, as Adrianople. His account of the rocks of Mount Olympus and northerly to the lake of Nice, has already been presented. Some additional facts will now be given.

* Mr. W. J. Hamilton, in a paper read two or three years ago to the London Geological Society, describes three periods of eruption in the Katakekaumene, all of them previous to historical dates. (Dr. Buckland's *Anniversary Address before the Geological Society, February*, 1840, p. 37.)

"My tour extended both into Asia and Europe, and I formed a general idea of the geology of the regions through which I passed, so as to be able to give it in a few words. From the chains of the Olympus to the great Balkan in Roumelia, there is a regular series of rocks. The Marmora produces no changes, nor any difficulty in the study of the formations, especially as the Princes' Islands continue the gradation of the series."

After describing the rocks of Olympus and northward, as previously given, Mr. Van Lennep adds:

"At Constantinople, and along the western side of the Marmora, the prevailing rock is secondary limestone, full of shells of various species, bivalve and univalve. (No. 627 is an example of the former.) So far as I know, all the other rocks are of volcanic origin. And similar to the above description are all the rocks of Roumelia, so far as I have been."

Mr. Van Lennep adds, in respect to a region southeast of Smyrna, in the ancient Pamphylia, some statements that may be interesting, though derived from European travellers. He was informed, that,

"In Pamphylia, there is a gradation from the seashore, to a distance of several days' journey inland, of shells, gryphites, corals, &c. Large plains are entirely underlaid by fossil coral, while the coast westward is entirely composed of primary limestone. Another traveller brought me, a few days ago, oysters, pectens, &c., which he found in an elevated plain six days' journey from Smyrna in a southeast direction. I hope, myself, to take a trip next fall from Macri to Satalia along the southern coast of Asia Minor; and, while I attend principally to missionary labors, I shall endeavor not to forget the interests of science."

No. 471 is a specimen of genuine bituminous coal, obtained by Mr. Perkins at Heraclea, some seventy or eighty miles east of Constantinople, on the south shore of the Black Sea. I am told it occurs there in considerable quantity, and if it does, it must be invaluable, both from its proximity to the capital, and its excellent quality. An analysis of one hundred parts gave the following results.

Earthy matter,	5.8
Volatile matter,	31.8
Carbon,	62.4
	100.

No. 642 was obtained by Mr. Van Lennep from the western banks of the Bosphorus, and appears to be coal identical almost with that from Heraclea. The lignite, No. 643, is from the same shore. On the shores of the Black Sea, in Thrace, is an interesting and extensive deposit of lignite. Nos. 329, 330, and 412, are from the Thracian bed, and for them I am indebted to Messrs. Homes and Hamlin. The former gentleman says, that the bed is five miles long, and from three to ten feet thick. The latter has sent specimens of the clay and limestone which contain the lignite. No. 409 is a friable clay, with traces of plants: No. 410 is a more compact clay, somewhat calcareous; and No. 411 is a limestone partly Öolitic and partly made up of small rounded grains of limestone. There can hardly be a doubt, from these specimens, that this lignite is in a tertiary formation, about which more, we hope, may ere long be brought to light. In the vicinity of the lignite bed, is a protrusion of trap, as appears from No. 421, which is a concretion of trap. From the manner in which the "lignite strata" dip from this trap, as described by Mr. Hamlin, I suspect its protrusion to be more recent than the deposition of the tertiary formation.

Some other specimens have been transmitted by Mr. Hamlin from the vicinity of Constantinople, which deserve notice. No. 400 is black limestone, from the Sutton black marble quarry, near the quarantine grounds, almost five miles up the Bosphorus from Constantinople, on the Asiatic side. No. 408 is rich pyritous copper, from the copper-mine called the Sutton mine on the Bosphorus, near the Black Sea, above Bugukdere. From the specimens of gray sandstone, Nos. 404, 405, 406, obtained in the vicinity of the mine, and the statement of Mr. Hamlin, that this is the predominant formation in that region, I suspect the copper to be connected, as it often is in other parts of the world, with new red sandstone. Nos. 415 and 416 are pebbles of siliceous slate: No. 417 of flint; and Nos. 418, 419, of jasper, from a vast pile of pebbles on the shore of the Black Sea, near the lignite bed.

Numerous specimens in my collection were obtained from ancient ruins. They consist of elegant marbles, porphyry, granite, &c., interesting as individual specimens, and to the antiquary; but since their original localities are not designated, I have thought it would be useless to the geologist to describe them. Many specimens of little importance, obtained from the rocks in place, I pass also in silence.

The third extensive region of which I wish to give some geological notices, embraces the ancient Armenia and a part of Persia and Georgia. For my specimens and descriptions I am indebted to Rev. Justin Perkins, except two or three specimens from Rev. J. L. Merrick. Mr. Perkins is now on a visit to this country, in company with Mar Yohannan, an intelligent bishop of the Nestorian church; and I have had full opportunity to converse with them respecting the points to which I wish to call the attention of this meeting. I cannot but bear testimony to the strong desire and effort manifested by Mr. Perkins, to collect and transmit specimens and information respecting the countries through which he has travelled. In his journey, for instance, from Persia to the Black Sea, a distance of seven hundred miles, over a very rough country, on horseback, and with his wife in feeble health, he contrived to bring along not less than seventy-five specimens of rocks and mineral waters; and in one instance brought on a fever by his efforts to climb a high peak of the Ararat range, in order to break a specimen from its summit. His route lay from the city of Oroomiah, on the shore of a large lake of the same name, through Khoy, thence to Bayazeed, near the west foot of Mount Ararat; thence to Erzeroum;

thence to Baiboot; and thence to Trebizond. I shall reverse this order in giving an account of the specimens.

An examination of the specimens and the statements of Mr. Perkins, establishes the fact, that limestone is the prevailing rock on this route; forming even the high mountain chains that are crossed. The greater part of it is a dull compact rock, which I suspect to be older than the cretaceous formation of Egypt and Palestine, chiefly because Prof. Bailey could detect in none of the specimens Polythalamian remains, like those of the chalk, or indeed any others. Occasionally, the specimens are chalky and marly, like those from Palestine; as No. 426, from Hassan Aillah and Erzeroum, and No. 445 from Baiboot. In short, I cannot doubt that nearly all the specimens belong to the fossiliferous rocks, and probably to the older varieties. Mr. Perkins also says, that while most of "the ranges of mountains between Trebizond and Erzeroum are soft limestone, here and there a naked granite peak peers above the general surface in sublime sterility." He did not, however, bring along any specimens of this granite.

It will be perceived, that the route of Mr. Perkins crosses, toward its eastern part, that broad tract of country, which, extending from the Azore Islands to the Caspian Sea, exhibits many traces of recent and extinct volcanic action. We see the evidence of this in many of the specimens, and in the mineral springs, some of them thermal, that occur in abundance.

The specimens No. 472, 473, of the rocks usually employed for purposes of construction in Trebizond, appear to be trachyte, with imbedded crystals of hornblende, though they approach certain aggregates sometimes found with the primary rocks. Another evidence of the igneous origin of the rocks around that city, presents itself in specimens No. 489 to 493, picked up on the shore of the Black Sea at that place. They consist of chalcedony, carnelian, agate, amygdaloid, &c., which must have come from rocks of igneous origin. No. 425 is another curious illustration of the same fact. For, if I mistake not, it is almost entirely composed of grains of olivine, a mineral abundant in basalt and lava. The rock containing it must be in large quantity somewhere in the vicinity, to produce enough to be gathered as sand upon the shore.

Still another confirmation of the same views, is found in numerous mineral springs which occur in the vicinity of Trebizond, upon the mountain ridges, though these do not necessarily indicate any very recent volcanic agency. Nos. 497, 498 are specimens of two of these springs; the latter twelve miles southwest from the city, and the other seven miles to the southeast. These waters are used by the inhabitants, especially the English and Americans of that city; and, if my analysis is correct, one of them at least may lay claim to a high character. I ought to say, however, that as I received these specimens only about six weeks ago, it has been impossible to go into all those minute details of analysis that would have been desirable. My results, however, may be of some service.

No. 498 belongs to the class of simple carbonated waters. The amount of free carbonic acid and of the earthy carbonates held in solution by this acid, was obtained by the method recommended by Berzelius, in his *Traité de Chimie*, by distilling the gas into lime-water. The amount of earthy carbonates and the other solid ingredients was so small, that I thought it useless to separate them; though they must somewhat increase the value of the water. Bromine I detected by the chlorine test, as recommended by Dr. Schweitzer, in his analysis of sea water. The carbonic acid must of course be less than exists in the water as it issues from the earth. I could detect no difference between the specific gravity of this and common water.

A wine pint of the water contains as follows:

Carbonic acid, ...	10.9 cubic inches.
Earthy carbonates, ...	0.5 grain.
Chlorides of sodium, of calcium, of magnesium, and a bromide, ...	0.5 grain.

This spring may undoubtedly be of some service in a medical point of view, especially as it contains the powerful ingredient bromine, although I could not detect iodine in it. But the other spring, No. 497, is much more powerful. Indeed, if I mistake not, it ranks among the best sulphureted waters known, though I did not find in it either iodine or bromine.

Specific gravity, ...	1.002

In a wine pint of the water I find,

Carbonic acid,	29.55	cub. inches.
Sulphureted hydrogen,	2.00	" "
Carbonate of lime,	2.67	grains.
Carbonate of magnesia,	1.44	"
Sulphate of soda,	2.24	"
Chloride of sodium,	3.25	"

Between Trebizond and Erzeroum, Mr. Perkins met with two springs similar to those above described.

" One of these springs," says he, " is situated about thirty miles east of Baiboot, in ancient Armenia, on a tributary of the river Joroke, about two miles above the junction of the tributary with the main stream. Around the spring a conical mound of limestone rock has been formed, (of which Nos. 459, 460, and 461 are examples,) by deposits from the water. I observed partially petrified matter hanging upon the spires of grass in the little rill running down from the spring. It was of the consistence of jelly, and seemed to be gradually hardening, as the water ran through it impregnated with limestone."

" The other spring is about twenty-five miles west of Baiboot, in the eastern extremity of ancient Pontus, on the Madden road, and about three miles above the point where this road leaves the Gumush Khan road. It is a ravine, about forty feet below the road, on the margin of a fresh-water stream. It is about three feet deep, and of nearly the same width; and its boiling and effervescence are so strong, that it attracted my attention as I was passing in the road. I had no previous knowledge of its existence, nor am I aware that it has been observed by any European traveller. I dismounted and went down to the spring, and was surprised to find another of a similar character, a few feet above, on the opposite side of the same stream, whose water, instead of rising to the surface of the ground, flowed through a lateral orifice into the brook. Both are so near this brook, that the water is carried away before it has opportunity to leave limestone deposits. The water tasted very much like that of the spring first named."

That the spring last mentioned above, deposits tufa to some extent, although a mound of it is not formed, appears from specimen No. 434, which was obtained at that place. The limestone there, also, from which the spring issues, (No. 433,) is almost exactly similar to the rock from which the spring thirty miles east of Baiboot issues (No. 462). These specimens will evidently give a good idea of the most common limestone along most of the route from Trebizond to Erzeroum. No. 476 is a distinct specimen of the older variety of argillaceous slate, from the vicinity of the spring, thirty miles east of Baiboot. It is tortuous and plumbaginous.

The temperature of the springs above described, Mr. Perkins did not ascertain, but thinks it was rather higher than that of the common springs of the country. The water tasted like that from a soda fountain, and both in appearance and taste resembles the spring on the east side of the lake Oroomiah, in which is deposited the famous Tabreez marble, or alabaster.

In passing from Baiboot to Erzeroum, twelve miles before reaching the latter city, and at Eleeja, there occurs a hot spring, whose temperature Mr. Perkins ascertained to be ninety-three degrees of Fahrenheit. Twenty-four miles east of Erzeroum, at Hassan Calleh, is another, whose temperature is ninety-six degrees. No. 463 is a specimen of the compact limestone from which the spring at Eleeja issues; and Nos. 464 and 465 are fine conglomerates, whose abundant calcareous cement is a deposit from this spring. When we reach the vicinity of lake Oroomiah in Persia, many other interesting mineral springs occur. But their nature and geological situation will be better understood after giving some general account of the rocks in that region, and of the lake itself. Previously, however, let us go back upon the route to Trebizond and notice a few more specimens.

No. 426 is a specimen of soft limestone, such as occurs all the way between Baiboot and Erzeroum; and, indeed, still further northwest than the former city; so as to make a distance certainly of one hundred miles. If it do not belong to the chalk formation, it may be tertiary. But Prof. Bailey found in it no cretaceous Foraminifera. It is associated at Baiboot with a compact limestone, Nos. 427, 428; and passes into a sort of calcareous sandstone, Nos. 431 and 432, which form the common building-stone of that place. At Madden, in Pontus, the building-stone is a gray lithographic limestone, No. 485. At Erzeroum, a beautiful gypseous alabaster, No. 487, is burnt and used as a substitute for limestone. It is quarried on the western branch of the Euphrates, at Aih Kelly, from twenty-five to thirty miles west of Erzeroum. It appears to be as beautiful and well adapted for ornamental purposes as any that is used for vases, &c., in Italy.

No. 484 is from the top of the first mountain ridge crossed in going from Erzeroum to Trebizond. It appears to be compact feldspar, from the ease with which it fuses, and is said to make up most of the mountain, except now and then a granite peak.

No. 435 is a pebble of siliceous slate, from the bed of the western branch of the Euphrates. No. 477 is compact limestone from Javislik, twenty-five miles south of Trebizond. No. 479 is a concretionary mass of trap, or lava, from the same place; and No. 478 a trap tufa, or breccia, made up of angular fragments of trap. Nos. 480 and 481, appear to be trap, with a stain of copper ore, from a high summit not far from Madden, where the Black Sea is just visible, in going toward Trebizond. In Madden is a silver mine, wrought by Greeks; and No. 488 is a specimen of the ore. The trap specimens just named were obtained not more than a few miles from this spot. No. 457 is from the declivity just above the mine, and seems, so far as we can judge from its lithological characters, to be graywacke slate. From these facts, then, we draw these probable conclusions: first, that this silver mine is in graywacke slate; and, secondly, that igneous agency has been in operation not far distant. This mine is fifty miles southeast of Trebizond, and thirty-five miles northwest of Erzeroum.

Nos. 436 and 437 are fine specimens of pyritous copper, from a mine fifteen miles east of Baiboot. The mine is wrought by Greeks, and it is said to be the most easterly point in Asia where that people are to be found. A little east of the copper mine is a very extensive deposit of dark serpentine, shown in No. 456. This locality is on the second mountain ridge west of Erzeroum, near forty miles from that city, and four miles west of the village of Roshapana.

A high range of mountains is shown on the best maps, extending westerly from Mount Ararat, and is called the Ararat range. From one of the highest peaks of this range, where it is crossed by the short Erzeroum road to Oroomiah, was taken No. 466; which is compact limestone, with a vein more crystalline. No. 467 was probably broken from one of these veins, and seems to be argentine. An analysis gave the following results in one hundred parts.

Earthy residuum, (?)	1
Carbonate of lime, ...	99
	100

East of Erzeroum, between that place and Hassan Calleh, is found the argillaceous limestone, or as I rather presume it to be, the marl, No. 445. Limestone continues nearly to the foot of Ararat. No. 444 is a hard porous variety, appearing as if deposited from a spring, from a branch of the Euphrates, eight miles west of Diadeen. No. 443 is a reddish compact limestone, from a point east of Diadeen, and twenty miles from Ararat. Near the west foot of that mountain, occurs the dark-colored limestone, No. 441. In the same vicinity was picked up the petrified coral, No. 440. Much further from the mountain, however, distinct vesicular lava, both in rolled pieces and in hummocks, is abundant. No. 442 appears like recent lava, and was found near the convent of Utch Kelasia, thirty miles west of Ararat. Nos. 438 and 439 are similar lava from Bayazeed, near the west foot of the mountain. One of these has upon it a coating of carbonate of lime. No. 229 was taken by Mr. Perkins from the foot of the mountain on its eastern side, several years ago, when he first entered Persia. It has an aspect even more like recent lava, than the specimens on the west side. Indeed, all the specimens confirm, if it needed confirmation, the statement of Prof. Parrot and others, that Ararat is made up of volcanic matter. Some travellers have even described craters, from whence eruptions have some time or other proceeded. But there is good reason to believe, that no eruption has taken place since the commencement of human history. Sir Robert Ker Porter says, that a register has been kept for eight hundred years at the convent of

Etchmiazren, of the state of the mountain, and that no eruption has occurred. Had one taken place even earlier, it is hardly possible that some account of it should not have been preserved. We may infer, therefore, that this mountain is to be reckoned as an extinct volcano.

As it is generally understood, that on this mountain the ark of Noah rested, it is not strange that a deep interest should be felt in every thing relating to it. It is an article in the creed of the Armenian church, that no one can ever reach its summit, where that nation suppose a piece of the ark still remains. Hence the inhabitants of that whole region still persist in denying that Prof. Parrot has ascended it. This is not so strange as it respects the Armenians; although Parrot was accompanied by a deacon of that church, and since that time a young man, Mr. Antonomoff, holding office in Armenia, has ascended the mountain. This was in 1834, and Parrot's ascent took place in 1829. But it is not so easily explained why the Musselmen, and even the English gentlemen who have resided of late in Tabreez, Erzeroum, &c. have all refused to believe that its summit has been reached.

This mountain has two principal summits, the Great and Little Ararat; the former seventeen thousand seven hundred feet above the sea, and the latter three thousand feet less. The highest peak is, of course, always covered with snow; but it disappears usually from the lower summit in the summer. As this mountain rises abruptly fourteen thousand feet above the vast plain on its north side, it forms one of the most magnificent objects which can be imagined. Mr. Perkins has now passed five times along its western side, and once along its eastern side, where runs the Aras, or ancient Araxes.

In describing Ararat as it appeared from the east side, or looking towards the northwest, Mr. Perkins says:

"We had near, advantageous, and delightful views of Mount Ararat, on our way to Persia. It is altogether unique in its appearance, and a very beautiful as well as most impressively sublime object. We saw its towering summit several days before we reached the mountain, overtopping all other mountains far and near. When within about sixty miles of it, we had our first distinct view of the whole mountain; and so lofty is it, that it seemed within eight or ten miles of us. Our nearest view was at the village of Khorvirab, about two miles from the base. The river Aras (the ancient Araxes) rolled between us and the mountain. The higher Ararat is almost a perfect cone. The upper part, about one third of the whole, is covered with eternal snow. The thermometer (Fahr.) ranged from ninety-five to one hundred and five degrees, when we passed it, August 11 and 12; and yet the scorching sun, under which we almost melted, seemed to make not the least impression on the hoary shroud of Ararat. The snow on its top and sides appeared of immense depth, and perfectly smooth, as though never broken or ruffled by the track of man, beast, or bird. On the lower Ararat, when we passed it, the snow lay only in patches."

"An immense plain, at least fifty miles in length, and from fifteen to twenty miles in breadth, perfectly level, and extremely fertile, stretches along the north and east sides of the mountain. At the northeast extremity of this plain is the city of Erivan; and twelve miles to the west, Etchmiazren, the celebrated Armenian convent, and the ecclesiastical metropolis of that nation. Around this plain are mountains, hanging in broken irregular piles, and indicating terrible convulsions in order to bring them into their present forms. At a distance they appear like ledges of lava; but, as you approach them, you generally find that their volcanic aspect is the effect of their naked exposure to the scorching sun."

"The physical features of the north of Persia," says Mr. Perkins, in another connexion, "are rather peculiar. There is no undulating land, or almost none. The country is divided into flat plains or valleys, surrounded and intersected by precipitous craggy mountains and ridges. The plains are very large and level. They are also extremely fertile.

"The western side of Mount Ararat presents a very different aspect from the eastern. It is less steep, symmetrical, and beautiful; but equally grand and imposing. About the southwestern base of this mountain, the surface of the ground, to the distance of fifteen or twenty miles, is rugged, and covered with stones from the size of a goose-egg to that of a man's head, which give strong indication of having been in a state of partial fusion."

I ought not, in this place, to omit a reference to the specimen of obsidian, No. 219, picked up on the road from Erzeroum to Georgia. Mr. Perkins states, that he found it on the table-land north of Ararat, as he passed easterly over a space not less than one hundred miles. This, among other facts, shows how extensively the volcanic agency, which threw up that mountain, reached around it. I would here suggest, although it may be mere conjecture, that, from an examination of the mountain ranges on the best maps, I suspect Ararat to stand at the point of intersection of two long lines of fracture, one running nearly north and south, and the other east and west. At such a point we should expect, if any where, the protrusion of melted matter.

As we might expect, Ararat and the surrounding country are quite subject to earthquakes. Tabreez, it is said, was destroyed some generations since; but the most recent event of this kind at Ararat possesses considerable geological interest. In a letter, dated Oroomiah, November 6th, 1840, Mr. Perkins says:

"We have had two earthquakes here in the course of the past summer. The first was very severe, in the vicinity of Ararat. Some parts of the towns of Erivan and Nakchevan were destroyed, and a village immediately at the base of Ararat is said to have been nearly buried by the masses of earth and rocks, that were shaken down from the mountain. The vast accumulation of snow, which had been increasing on the top of the mountain for so many generations, was broken into pieces, and parts of it shaken down the sides of the mountain, in such immense quantities, that, it being midsummer, and the snow descending into the warm region, and suddenly melting, torrents of water came rolling down the remainder of the mountain, and flooded the plain at some distance from its base."

An extract from a Russian Gazette, prepared by an officer in the vicinity, confirms these statements, and adds many details. The first shock occurred June 20th, before sunset, and precipitated an avalanche of snow, ice, and rocks, which "swept away the monastery of St. James, and destroyed a village at the base of the mountain. At seven o'clock, P. M. of the same day, three thousand one hundred and fifty-seven houses were destroyed by an earthquake, and thirty-three men and two hundred and fifty-three cattle were destroyed. On the 24th of the same month, a second more terrible avalanche descended from Ararat, and spread over the surrounding country to the distance of fourteen miles, destroying many houses in several villages." These statements were also confirmed to Mr. Perkins by the Emeer Mirzam, commander-in-chief of the Persian army, who happened to be in the vicinity of Ararat at the time.

The next spot of geological interest to which I wish to call the attention of the Association, is the lake of Oroomiah, in the northwest part of Persia, and nearly one hundred and fifty miles southeasterly from Ararat. Its length is full eighty miles, and its breadth in some places thirty miles. Next to the Dead Sea, its waters are more highly impregnated with salts than any that have yet been analyzed. Like the Dead Sea, it has no outlet; but instead of being depressed below the level of the ocean, like the Dead Sea, it is probably not far from four thousand feet above the Black Sea. The city of Tabreez is situated on its eastern shore, not far from twenty miles distant, and gentlemen connected with the English embassy there, have determined, barometrically, that that city is about four thousand feet higher than the Black Sea; and Tabreez stands nearly on the same level with lake Oroomiah. Another fact renders these statements probable. By looking at a good map of that region, we shall see that only a few short streams flow into the lake, while several other streams take their rise almost in the same place, and run a vastly longer course, some of them, as the Aras, for instance, into the Caspian Sea; and others, as some tributaries of the Tigris, into the Persian Gulf. Now unless those which fall into the lake have a much more rapid descent than the others, and Mr. Perkins informs me they have not, the lake must lie at a much higher level than the Caspian Sea, or the Persian Gulf. But we know that the former is only one hundred and eight feet lower than the Black Sea; and hence Oroomiah must be much above it.

The specific gravity of the water of this lake I find to be 1155, which is a mean of several trials with the hydrometer, and by weighing a portion of the water.

1593.6 grains were evaporated, and left a residuum of salts equal to 325.5 grains; which, in 500 grains, would be 102.1 grains.

I have met with no analysis of the water of this lake, except one by Dr. Marcet; and, as he possessed but a very small quantity of it, I thought it desirable to repeat the process.

In five hundred grains of the water, I find

	Grains.
Chloride of calcium,	0.74
Chloride of magnesium,	5.76
Chloride of sodium,	90.58
Sulphate of soda,	5.67
	102.75
Amount of salts by evaporation in 500 grains,	102.10
Excess,	65

This excess is of course to be imputed to errors of analysis. Had time permitted, I should have repeated the process more frequently than I have done. Dr. Marcet gives the result of his analysis of five hundred grains by merely stating the precipitates produced by certain reagents, as follows:

	Grains.
Muriate of silver,	111.5
Sulphate of barytes,	66.0
Phosphate of magnesia,	10.5

I have not reduced the above analysis so as to compare it accurately with my own. But it is obvious to inspection, that he found considerably more sulphuric acid in this water than I did. I ought to mention a fact, however, that may account for this difference, without imputing it to errors of analysis. When I first received the water, it was so strongly impregnated with sulphureted hydrogen as to tarnish silver at once. Now must not this gas have resulted from the decomposition of the sulphates in the water? If so, as Dr. Marcet mentions nothing of the kind, it may explain the smaller quantity of sulphates which I was able to find. Again, the specimen which I analyzed was taken from the north end of the lake; and it may be his was obtained from some other part, where springs abounding in sulphates empty into the lake. The small quantity of lime which I found, may have had a similar origin. I tested for iodine without success; but chlorine gave distinct indications of the presence of bromine.

The near approach to saturation of this water with common salt, excited the inquiry, which every geologist knows to be one of great interest, whether around the shores, or at the bottom of this lake, there may not be permanent deposits of that salt. Mr. Perkins has pursued the inquiries which I put to him on this subject in a very judicious and satisfactory manner. I give the result in his own words:

"The water of the lake rises every spring from three to five or six feet, during the annual freshets from rains, and the melting of snow on the surrounding mountains: and, as these cease, the lake gradually subsides to its summer level. In most places the land near the lake is flat, and but a few feet higher than the ordinary surface of the water. It is, therefore, extensively overflowed in the spring; and as the waters of the lake gradually subside, a very thin incrustation of salt is left on the land thus overflowed. This coat, however, is so thin, that it is difficult to collect it without a mixture of mud and sand."

"To procure salt clean and in large quantities, small ridges or intrenchments are made, eight or ten inches high, enclosing from one to four acres each, as the surface is more or less sloping. These ridges detain a sufficient depth of water, when the body of the lake retires, to deposit a layer of pure white salt (No. 225,) from one to three and a half inches thick, which crystallizes by the evaporation of a summer's sun. No other labor is required until the salt is to be collected. Over many miles of these flats, thus covered with a pure sheet of snow-white salt, I have rode to-day."

"The natives tell me that all the salt, which is not collected, (whether within or without the little ridges thrown up as entrenchments,) disappears during the rains and snows of the year."

"The natives also say, that for the last five or six years, from some cause unknown to them, the mean level of the waters of the lake has been several feet higher than formerly. And some say that before this rise, salt banks had gradually accumulated on the shore of the lake, which were permanent from year to year. All the natives whom I have consulted, do not agree on this subject."

Mr. Perkins adds in a postscript, that having consulted a bishop on these points, who lives on the shore of the lake, and whose testimony is unimpeachable, he has "no doubt but that such salt banks did exist on the shore, now covered with the increased waters of the lake. This bishop also stated of his own accord, that the surface of those salt banks was usually covered with a layer of sand, and that in penetrating into them you would pass through alternate layers of salt, and of sand or earth."

The bishop here referred to was Mar Yohannan, now in this country: and he still repeats the above statements, and adds another of importance. He says, that near his place of residence (Gavalan) there is a small pond, covering perhaps an acre, separated from the lake by a narrow and low sand-ridge, which has a permanent deposit of salt upon its bottom. Dr. Daubeny states this to be the case with lake Elton, and several other lakes in the vicinity of the Caspian Sea.

Upon the whole, the question, as to the permanent deposits of salt in lake Oroomiah, demands still further examination, although I doubt not that many respectable and honest natives can be found who live on its shores, and who believe that formerly such deposits were permanently formed.

The same may be said of another tradition, which prevails extensively among the inhabitants on the shores of this lake, and is even entered upon the public records of some of the villages, especially around its northern extremity. It is stated, that, sixteen or eighteen years ago, the waters of the lake suddenly disappeared, and left the bottom bare for a great distance, and that some young men, who followed the retiring waters, came at length to a great chasm. The waters, it is said, soon rose again to their accustomed level. Now this is not an impossible phenomenon, in a region so subject to earthquakes. But the difficulty is, that many natives seem to know nothing about it, among whom is Mar Yohannan. It is merely possible, but perhaps not probable, that such an occurrence might have happened at one end of the lake, without producing very marked effects at the other end.

Whence comes the extreme saltness of this lake? A few facts will, I think, give a satisfactory reply to this question. In the first place, the country to the east and north of the lake contains some of the most remarkable deposits of rock salt in the world. Large beds of it occur near Tabreez, in Red mountain; and from that mountain there comes down a stream, "several rods wide, of salt water; not so salt as the water of the lake, but too salt for comfortable use, though the natives do use it, which runs into the lake. Its name is *Âjee chai*, bitter, or brackish river." This mountain is about forty miles from the lake; but a salt plain extends from thence to the lake. Another bed of rock salt at Khoy, is only eight or ten miles from the north end of the lake. Here, then, we have an abundant source of the common salt in its waters. Its other ingredients may be derived from the remarkable mineral springs in its vicinity.

"At one locality," says Mr. Perkins, "about twenty miles south of Tabreez, and the same distance from the lake, near the village of Leewan, three springs issue within the space of eight yards of one another, and every one strikingly different in the quality of its waters from the others. One is hot, a second is acid, and a third is sulphureous, and highly fetid. And a few rods from these springs, on the opposite side of a stream, is a fourth, whose waters are impregnated with iron."

On the eastern shore of the lake, and quite near it, are the remarkable springs that deposit the famous calcareous alabaster, called Tabreez marble, which I shall notice more particularly further on. On the southeast shore of the lake, is another spring, which evolves carbonic acid, and deposits marble to some extent. On the west side of the lake, is a sulphur spring, about fifteen miles north of the city of Oroomiah. About thirty-five miles north of that place, on the north side of the mountain, between the district of Salmas and Oroomiah, is a hot sulphur spring, greatly resorted to by the natives, and depositing marble. It is four or five miles from the lake, is called *Issee Soo*, that is, *hot water;* and the present Prince Governor is now fitting up an establishment there for warm baths. Another salt and hot spring exists near Khoy. Surely, in springs so numerous, which must nearly all flow into the lake, we have a prolific source of the less abundant ingredients of that lake, although it is true that these springs have not been analyzed. But we know that they are carbonated and sulphureted springs, and probably they contain ingredients similar to springs of the same general character in other parts of the world.

I would here remark, that, in the facts above stated, we see the probable origin of the saltness of many of the lakes of Central Asia. The whole of that vast region appears to have been more or less subject to volcanic action; and as one of the results, a vast amount of chloride of sodium and other salts, has been produced. Oroomiah is thus rendered too salt for any sort of animals to live in its waters: though, from the fact that the flamingo is very commonly found wading along its shores, I strongly suspect that some sort of worms is found in the mud beneath the waters. But the Caspian is far less salt, and furnishes fine fish in abundance. The same is true of lake Van, which lies west of Oroomiah, and is of about the same size. In lake Elton, and some others in Asiatic Russia, already mentioned, the principal ingredient is chloride of magnesium, to which circumstance Prof. Daubeny attributes the precipitation of rock salt upon their bottom.

I have received no specimens from the vicinity of the Caspian Sea, except No. 552, from its shores. This sand is chiefly magnetic iron ore: but it contains also, manganese, and grains of olivine. This last mineral shows that the region around must contain volcanic rocks.

I ought to state, that the water from lake Oroomiah, whose analysis has been given above, was obtained about the twentieth of September, from the north end of the lake. A specimen recently brought by Mr. Perkins, which was procured near the city of Oroomiah on the first of July, that is, when the lake must have been much higher than in September, has a specific gravity of 1114, considerably less than that of the former, indicating the presence of a less quantity of salt; which is what we should expect.

I shall now give a more detailed account of the geology of the country around Oroomiah, so far as I am able to do it, from the specimens and descriptions furnished by Mr. Perkins.

"The plain of Oroomiah," says Mr. Perkins, "is about forty miles in length, as it lies upon the lake, and it extends back to the Koordish mountains, a high range of which, sweeping around in a semicircular direction, its two extremities reaching the water's edge, encloses the plain like a vast amphitheatre. This plain, at its widest point, where it swells a few miles into the lake, as well as retreats back into the curve of the mountain range, is about twenty miles broad. Its *appearance* from the heights back of it, is that of a perfect level: so much so, that the beholder can hardly resist the idea that it is a bed of tide waters, which is just laid bare by their ebb, and is soon to be enveloped by a returning flow. In fact, however, there is a considerable descent from the mountain side of the plain to the lake: and the three considerable rivers, (each from one hundred to two hundred feet wide,) which roll down through rugged ravines in the mountain range, flow across the plain and pour themselves into the lake with rapid currents. I am not aware, that the lake ever does overflow more than a mile or two of the shore, even in the spring, and it has no tides."

"The plain of Oroomiah, in reality as well as in appearance, is extremely fertile. With the adjacent declivities of the mountains, comprising an area of about six hundred square miles, it sustains three hundred and fifty villages; almost every inch of the soil being under cultivation. Its almost entire and frequent irrigation, by means of small canals from the rivers, and the immense annual growth and decay of vegetation, are the secret of the unhealthiness of our climate."

That the causes here suggested by Mr. Perkins are among the sources whence disease originates on the plain of Oroomiah, I do not doubt; but I must be allowed to suggest, as other causes, the great quantity of sulphureted hydrogen generated by the lake, and of carbonic acid from the mineral springs in the vicinity. These two gases, I believe, are now generally regarded as among the most pernicious of miasms. Not improbably these gases are produced from the soil of that region, especially in low and damp places, as well as from the lake. Alkalies or lime-water, could they be employed, would absorb the carbonic acid; and nitric acid, or burning sulphur, the sulphureted hydrogen.

"The soil on the plain of Oroomiah," continues Mr. Perkins, "is a dark-colored alluvium. Having occasion a few years ago to superintend the digging of a well on our mission premises, I observed that this alluvium was two and a half feet thick; and I have observed the same elsewhere, as I have seen the natives digging canals for irrigation on different parts of the plain. In digging our well, we were obliged to go down about sixty feet for water. After passing through the alluvial stratum, we came to drift, consisting of coarse sand, gravel, and pebbles; the larger stones being of the size of the fist, and many more than twice as large; the whole much resembling the soil on the hill in front of your college (at Amherst) where we labored to form terraces when I was a student there. This drift we found to be eighteen feet thick. We next came upon hard yellow clay, which continued until we reached water; that is, about forty feet. Such I am informed is the usual order and thickness of these deposits."

"You will be surprised to learn, that our well-diggers penetrated the earth to this depth without the least protection of anything like a curb. They dug the well about three feet in diameter, and enlarged it a little as they descended. They dig in this way at all seasons of the year for the moderate sum of eight to twelve cents per yard."

In conversation with Mr. Perkins, he informs me, that the soil of this remarkable plain is quite similar to that of the prairies of our Western States; and one of his fellow missionaries, who is familiar with our prairies, has remarked, that he had never seen a richer soil, except in one or two places, than that of Oroomiah. Whether the deposits of gravel and clay below the alluvium is to be regarded as connected with drift, or tertiary strata, we have scarcely materials enough to decide.

I incline to the belief, that the fertility of this plain depends in a great measure upon the common salt, which probably exists in the soil of that region generally. It is so much diluted by irrigation, as to prove an admirable manure. A salt desert is an image of perfect sterility; but let fresh water enough be brought over it, and I think we have facts to warrant us in saying, that the desert will be changed into a Paradise of flowers and fruits.

As we come to the hills surrounding the plain of Oroomiah, limestone is for a time the predominant rock. This is evidently of secondary or tertiary character. Some of it, as Nos. 210, 213, and 214, is chalky, and resembles the limestones of mount Lebanon. But Prof. Bailey could not find in it any remains of Foraminifera. A few of these varieties I analyzed.

No. 214 is from a mountain fifteen miles northwest of the city of Oroomiah. It is used for purposes of building, and by the Nestorians for gravestones, in large blocks. The specimen analyzed was broken from the monument over Mrs. Dr. Grant, the wife of an American missionary. In one hundred parts I found,

Earthy residuum, ...	0.33
Carbonate of magnesia, ...	0.83
Carbonate of lime, ...	98.84
	100.00

No. 210 is another variety from the same mountain, and is used in Persia for hydraulic cement. The native name for this rock is *Ahak.* In one hundred parts I found,

Earthy residuum, ...	0.66
Carbonate of magnesia, ...	0.55
Carbonate of lime, ...	98.79
	100.00

If this is a fair specimen of this limestone, and if our notions respecting hydraulic cement are correct, I hardly know how to explain the fact, that this rock should produce such cement. But I believe the analysis to be essentially correct, and I must leave others to explain the difficulty.

A very common and impure limestone is Nos. 200 and 201. It occurs on the mountain west of the plain, in layers from two to four inches thick, and is used extensively for paving, building, and gravestones. I should suppose this might make a better hydraulic cement than No. 210.

Connected, probably, with the limestones above described, gypsum is abundant. It occurs in an insulated hill, fifteen hundred feet high, on the plain of Oroomiah, whose central part is composed of primary rocks. No. 212 is an example of this gypsum. It occurs, also, in the hills on the west side of the plain, and is extensively used in that country as a substitute for limestone, in forming plaster for walls. The precise process for converting it into mortar, and its comparative durability, I have not been able to learn, as the natives seem to confound this with limestone.

I suspect No. 211 to be gypsum, mixed with a few per cent. of carbonate of lime. Certainly it exhibits a lively effervescence with an acid, but most of it remains undissolved. It is softer than common gypsum.

In passing into the mountains west of the plain, extensive deposits of coarse conglomerate are met with, but of their nature I cannot judge without a specimen.

Finally, the prevailing rock in those mountains is granitic gneiss. No. 198 is an example, and has the appearance of granite; but Mr. Perkins says, it is in strata, which have a southeasterly dip from twenty to thirty degrees. I doubt not, therefore, that the Koordish mountains are composed of primary rocks; and if we can place dependence upon the maps of that country, these mountains extend northerly nearly to Ararat; and southerly, far towards the Persian Gulf. They seem to form the great watershed between the streams that flow westward into the Tigris and Euphrates, and eastward into the Caspian Sea. I doubt not that along that ridge will be found very extensive deposits of crystalline rocks.

Some of the small islands in the lake are said to be composed of quartz rock. No. 199 is from near Tabreez, and is used with the incinerated seaweed, No. 226, growing on the borders of the lake, for making glass. It is said to be abundant in various parts of Persia. Some of the islands in the lake are composed of limestone. Petrifactions occur on some of the islands, and though I have no specimen, Mr. Perkins is confident, that some of them are vegetable and others animal.

Mr. Perkins was informed by the present Prince Governor of the province of Azerbijan, whose name is Malek Kasem Meerza, that on a hunting excursion in the mountains west of Oroomiah, he discovered a magnificent cataract, about twenty miles from the lake, where the water tumbles wildly from cliff to cliff from the height of nearly four hundred feet, showing the rainbow frequently upon its spray. This Prince shows a strong disposition to introduce European improvements, and lately set men digging for coal in the mountains, on no other ground, than that coal frequently occurs in the vicinity of iron; and he knows that the latter is found in those mountains.

I have alluded to the great quantities of fossil rock salt found in the region to the east and north of Oroomiah lake. The plain between the lake and Tabreez is called a salt plain, from the presence of this substance. Near Tabreez there rises a naked mountain, which, from its color, is called Red Mountain. Nos. 203 to 208, are specimens of the rocks found there; and one cannot look at them without perceiving that they bear a strong resemblance to varieties of the new red sandstone of Europe and America. Nos. 203, 204, and 207, however, appear as if they had been exposed to a strong heat, which has nearly expelled the red color. No. 206 is a conglomerate. In this rock occurs an extensive deposit of rock salt, the purest that I have ever met. No. 209 is an example, as limpid as rock crystal. And on examining it chemically, I cannot detect a trace of a sulphate, or of lime, or of magnesia, or of iodine, or bromine; most of which are usually present in fossil salt. It is the first specimen of fossil salt which I have ever found perfectly free from foreign ingredients. In one of the crystals there was a fluid, as shown by a moving bubble.

So far as lithological characters can go, the probability is strong, that this formation is the new red sandstone. I have another fact in favor of the same view. On the plain of Khoy, eight or ten miles northwest of the lake, is another extensive deposit of salt, connected with a similar red rock, with limestone, (No. 453,) and with gypsum, (No. 455.) The bed of salt is ten feet thick, and is quarried, although not as pure as that at Tabreez. Is not the probability very strong, that the deposit containing these minerals is the new red sandstone? Examining the salt from Khoy chemically, I find in it sulphuric acid, lime, and magnesia, in about the usual quantity, but neither bromine nor iodine.

As we go northerly from this lake, we shall find, according to the researches of our countrymen, Messrs. Dwight and Smith, another bed of salt, a little north of Nakchevan, east of the Aras, in Georgia: a second bed, a little northeast of that place; a third, west of Erivan; and, indeed, all along the Aras, salt is abundant a little beneath the surface, as far as Kars, and perhaps further. If now we look southerly from Tabreez, we are met upon the maps with the great salt desert in the central parts of Persia, extending almost to its southern borders; and there can be little doubt but this is a continuation southward, of the saliferous deposit in the north of Persia. If so, it must be nearly one thousand miles long, and of great breadth. Again, it can hardly be doubted, that this formation reaches the Caspian Sea, since that is salt; and also other inland lakes in Tartary; so that probably the formation extends as far northeasterly from Oroomiah, as it does northerly or southerly. We catch, indeed, but glimpses of the extent of this formation; but we see enough to make it probable, there is not such another salt deposit on the globe; enough to show us what an interesting task lies before some future geologist, in tracing out the geology of these wide regions.

I have alluded to the deposition of marble, or alabaster, by certain springs in the vicinity of lake Oroomiah. What is called the Tabreez marble has been repeatedly described by travellers; but I doubt whether very definite geological ideas have yet been entertained respecting the mode of its formation. With the exception, perhaps, of a deposit of travertin around Rome in Italy, resembling statuary marble, I am not aware of any case besides those around Oroomiah, in which the most beautiful marble is produced by springs. The Tabreez marble, of which Nos. 220 and 221 are examples, is usually of a yellowish or light blue color, perfectly compact, and so translucent, that it is used in thin slices for the windows of baths and other places, like the *phengites* of the ancients. It occurs not far from Maraga, on the east side of lake Oroomiah, and about half a mile distant from it. Immense quantities of this alabaster (for it is the true calcareous alabaster) have been dug and carried away. The common opinion is, that the springs now deposit it; but one or two facts have led me to suspect that this may not be the case. Above the marble there lies a deposit, several feet thick, of common tufa, or travertin. Now my suspicion is, that this tufa is all the deposit which has been formed since the springs assumed their present state; and that the alabaster was deposited when their temperature was higher, and when perhaps they were beneath deep waters. However, this opinion is little better than conjecture. That this substance often has a concretionary structure, appears from No. 220.*

From the resemblance of the calcareous alabaster from the Pasha's palace in Cairo (No. 385), as already described, I was led to anticipate a similar composition of that from Maraga. And, indeed, it is perfectly soluble in acid. But I found the ingredients in one hundred parts to be,

Proto-carbonate of iron, ...	2.93
Carbonate of magnesia, ...	1.33
Carbonate of lime, ...	95.74
	100.00

A spring similar to that which produces the marble above analyzed, exists on the southeast shore of the lake; but whether it has deposited much marble I cannot say. Another exists on the promontory near Salmas, as you begin to ascend the northern side of the mountain. No. 470 is an example, and shows the concretionary structure exhibited in that from Maraga. By analysis, I find that one hundred parts of this specimen contain,

Proto-carbonate of iron, ...	1.95
Carbonate of magnesia, ...	1.06
Carbonate of lime, ...	96.99
	100.00

* Morier gives a detailed account in his travels, of the manner in which this alabaster is deposited by the water of these springs; but his description appears to me misty and unsatisfactory. Neither he, nor any other writer whom I have seen, explains how it is, that the marble is covered by several feet of porous or common travertin.

Will the facts above stated throw any light upon the general subject of the origin of rock salt? That this substance in Asia, as in other parts of the world, is usually connected with rocks of rather recent igneous origin, seems fully established. But do not the facts respecting the exceedingly salt lakes of Oroomiah, Elton, and others, render it extremely probable that beds of salt, alternating with beds of earth, may have been formed,—indeed, are now forming? So that, although originally of volcanic origin, subsequent alluvial agency may redeposit it. And will not this double origin of the substance best accord with facts?

I will refer in this place to an interesting specimen of marble, obtained by Rev. Mr. Merrick, in the ruins of Persepolis. It is a dark gray, argillaceous, bituminous limestone, with casts of univalve shells. (No. 202.) In dissolving this stone in hydrochloric acid, it gave off a strong bituminous odor; but the quantity of bitumen in it is not very large. I found in one hundred parts,

Earthy residuum, ...	2.33
Carbonate of magnesia, ...	2.21
Carbonate of lime, ...	95.46
	100.00

It would be strange, if such limestone would not form a good hydraulic cement. But the locality of the quarry from whence it was taken, I do not know. It is not a rock, however, that would be carried a great distance, because not handsome; and, therefore, we should expect to find the quarry not far from Persepolis.

No. 216 is an exceedingly rich ore of copper, from a mine about sixty miles northeast of Tabreez; and of course not far from Georgia. It is mainly native copper, incrusted with the green and blue carbonates, and mixed with the red oxide. The native copper exists in some of the cavities in crystals. This mine is extensively worked by the Persians, and is said to be very rich. A large number of cannon have been cast from it for the Persian government.

Phenomena of Drift in Western Asia.

With a few statements respecting the phenomena of drift in Western Asia, I shall close this paper.

This is the most difficult of all geological subjects, on which to obtain information, in countries whose geology has not been thoroughly explored. The most intelligent traveller may pass through regions prolific in marks of what I call glacio-aqueous agency, without noticing them, unless he has been previously familiar with the phenomena. Still I think our missionaries have furnished a few facts, making it probable that eastern countries are not destitute of such phenomena.

To begin with Armenia. Before Mr. Perkins left this country, he accompanied me to a striking example of what have been of late called moraines, produced not by glaciers alone, but by ice crowded along the surface in any mode, whether by expansion, water, or gravity. I requested him to inform me, whether any similar phenomena came under his notice in the east. Soon after his arrival there, he says, that on the vast plain to the north of Ararat, and considerably distant, "we passed many sections of drift, much like the one we visited back of Amherst." On his return recently to this country, he thus writes from Trebizond, under date of August 13th, 1841.

"Just back of the city of Trebizond, is a mountain, about six hundred feet high, which runs from the seashore around the city, and which is called by the natives, *Bos Topa* or *Azure Hill.* About half way up this mountain, Mr. Johnston (American missionary there) pointed out to me some striking geological features. Directly on the declivity is a section of strongly marked drift, consisting of coarse gravel and sand. A small ravine having conducted the water down to the top of one of these hills, it has been gullied to the depth of twenty feet, which reveals the sand and pebbles to that depth. Further along, on the side of the mountain, and at just the same height, we observed, where a road had been excavated, a deposit of the same drift in the crevices of the rocks."

"I have often observed, in different parts of Western Asia, particularly in Persia, hills of drift; but none so regularly conical, or rather *inverted-punch-bowl-shaped,* as those on the declivity of this mountain. And I have very seldom observed the *diluvial punch-bowl hollows*, which so abundantly occur in America. Mr. Johnston, however, informs me, that he observed very striking examples of such hollows in ancient Cilicia, on the river Halys, near the present town of Sivas. In the same region, too, he observed a section of alluvium and drift, (which was laid open by a rapid stream, issuing apparently from the ground at the head of the section,) and which was four hundred feet high; the whole presenting very striking geological features."

It is difficult not to recognize in the preceding accounts, what are called ancient moraines, by Agassiz, Buckland, and others. Those at Trebizond have probably been brought into a conical shape, and are insulated by alluvial agency, subsequent to their original production. Some insulated cones of this description occur on the plains of Oroomiah. There are not less than twelve or thirteen of them, and some of them, according to Mr. Perkins, cover an acre and a half of ground, and are from seventy-five to one hundred feet high. In that region they are universally regarded as artificial, and the work of the ancient fire-worshippers. For on digging into them, walls of stone are found laid up to their centres, and much of the soil seems to be little else than ashes.

It may appear presumptuous in me to doubt the artificial origin of these mounds. But in the first place, similar mounds occur in various parts of the northern hemisphere, and are almost every where regarded as artificial; whereas geologists are discovering from time to time, that many of them are the result of aqueous agency, either during the drift period, or the alluvial. In the second place, if these mounds existed before man, it is not strange that man has chosen them as a place on which to erect forts, perform religious rites, and to deposit the dead. It would be reasonable to expect, that the fire-worshippers would choose them as the spot best fitted for keeping up the perpetual fire. In the third place, Mr. Perkins informs me, that some of them at least, where he saw them dug into, exhibited a stratified arrangement of their materials. This fact appears to me quite decisive in favor of their aqueous origin; for what human skill can arrange fine and loose materials in the manner that is done by water? Finally, the work of erecting them is too great for a people in the rude stages of society. I cannot, therefore, but strongly suspect that they may be the remnants of a formation which once spread over the whole plain; the most of which has been swept away. I doubt, however, whether they are connected with drift; since the materials composing them are fine, and not gravel, and are, moreover, sorted or stratified.

Robinson and Smith have described a large number of tumuli of gravel on the west side of the Jordan, near Jericho. As some of them were covered with the remains of buildings, it was very natural to suspect them to be artificial. But the great number scattered over the plain, rendered the supposition improbable. Dr. Robinson was so kind recently, as to accompany me to a region of tortuous and round-topped moraines in Amherst, that I might satisfy myself whether their materials are similar to those around Jericho. He declared that there was no difference, except that those in Palestine are insulated cones, and those in Amherst irregular and tortuous. The insulated ones, however, are very common in New England. I cannot, therefore, but strongly suspect, that those in Palestine were produced by glacio-aqueous agency.

In passing through the Wady el Arabah, south of the Dead Sea, Dr. Robinson describes some examples of bowlders and of gravel and sand-hills, of such a character and extent, as to lead one strongly to suspect them to be the result of the same agency. But further observations will be necessary to settle the question.

The most decisive example of glacio-aqueous agency which I have met with as occurring in Western Asia, is given in the Journal of the American missionary, Mr. Beadle, in Northern Syria,— as related in the Missionary Herald. In travelling northerly along the coast from Beyroot, sixty or seventy miles, he "reached a volcanic region with a remarkable locality of greenstone. The pebbles from this locality are scattered the whole distance to Beyroot. At that place they are quite small, but gradually increase in size as you advance to the north, and terminate entirely in this locality." If such a case as this had been found in Northern Europe, or New England, no one would have doubted at all that it was a genuine example of the dispersion of bowlders during the period of the deposition of drift. Some might, indeed, suppose that these bowlders and gravel were carried southerly by the waters of the Mediterranean, when their whole track was beneath the waves. But such a dispersion could not have taken place without ice; and to introduce this, carries us back to the drift period, which is admitting all that I contend for. Beyroot lies in north latitude, thirty-four degrees, and this is certainly further south than any glacio-aqueous agency has been hitherto detected.

But I must close; and I cannot do it in a better manner, than by quoting a few remarks from a private letter from Mr. Perkins, in 1839, on the importance of a knowledge of geology to the missionary. "Did not my missionary work," says he, "press upon me so constantly, and with such mountain weight, I should feel strongly tempted to study geology, (of which I know very little,) so wonderfully interesting, in a geological point of view, does the face of Persia appear to me. Indeed, I often feel that this interesting and important science has peculiar claims on American missionaries. Visiting, as they do, all portions of the world, they enjoy opportunities of contributing to it, with almost no sacrifice of time or effort, which are possessed by no other class of American citizens. I know not that I can better atone for my own deficiency in this respect, than by requesting you, in my behalf, to urge upon the missionary students in college, the high importance of their obtaining a good practical knowledge of geology and mineralogy, while attending your lectures, as they would enhance their usefulness in future life. It is the combined light of ALL TRUTH, *scientific* as well as *religious*, which is to render so perfect and glorious the splendors of millennial day."

APPENDIX. — A part of my collection of specimens from Asia, consists, as already intimated, of rocks and minerals, sent from Ahmednuggur, in India, more than one hundred miles east of Bombay, by Rev. E. Burgess. They were obtained in the vicinity of that place; and show that trap rocks make up most of its geology.

But they show, also, that these rocks are probably a rich repository of zeolitic and chalcedonic minerals; and, therefore, I append a catalogue, although it has long been known that that part of India afforded such specimens, and it may be that this particular locality has been described.

Nos. 556 to 559. Compact basalt, or greenstone: the common rock.

Nos. 560 to 565. Tufa, or toadstone: the cavities filled by green earth, heulandite, and calcareous spar.

Nos. 566, 567. Amygdaloid: cavities filled with beautiful green earth (?) and natrolite, or mesotype, in silken tufts.

Nos. 568 to 573. Amygdaloid: the cylindrical cavities filled with chalcedony, coated by green earth, calcareous spar, quartz, and zeolitic minerals.

Nos. 574 to 579. Trap tufa, with nodules of calcareous spar and zeolites; except No. 577, which is brick-red amygdaloid, with druses of calcareous spar.

No. 581. Stalactical chalcedony, with zeolites.

No. 582. Chalcedony, having the form and appearance of a vegetable stem, an inch and a half in diameter.

Nos. 583 to 587. Geodes of crystallized quartz. Crystals hexahedrous, with hexahedral summits.

No. 589. Quartz geode: crystals six-sided prisms, with trihedral summits.

Nos. 590 to 592. Stalactical quartz: the cylinders from an inch and a half to three inches in diameter, and often six inches long: sometimes compact, with a mamillary or semi-crystalline surface: sometimes the crystals have trihedral summits.

Nos. 594 to 600. Rhomboidal crystals of calcareous or Iceland spar: generally transparent, sometimes smoky.

No. 605. Soft compact limestone: a common rock.

No. 606. Thomsonite: in radiated masses, four inches long.

No. 607. Stilbite, in radiating masses.

Nos. 608, 609. Crystallized Apophyllite, with quartz. The crystals show two four-sided pyramids, slightly truncated at the summit, and at their bases: but the faces of the original primary right square prism, are almost obliterated.

No. 613. Brain Coral (Meandrina), from the island of Zanzibar, broken from a rock three hundred feet above the ocean.

Remarks upon Casts of Mud Furrows, Wave Lines, and other Markings upon Rocks of the New York System. By James Hall, *of Albany, N. Y.*

The surface of strata in all the shaly or intermingled shaly and sandy deposits, from the oldest of the kind up to the coal, and even in the new red sandstone, present us with many peculiar markings, which, for the most part, can be referred to no known organic forms, and from analogy are considered as due to the influence of physical causes in operation at the time of the deposition of the strata. Among these have been recognized the ripple-mark, and the impression of rain-drops; the one indicating shallow water or a dry beach, and the other a condition of soft mud, which could be impressed by the force of rain-drops. The great depth of deposits above these, prove their subsequent subsidence, allowing other strata, often marked in the same manner, through many feet in thickness, to be deposited upon them.

The most remarkable rock impressions are those of the feet of reptiles and birds, which are likewise often found in connection with those alluded to.

Besides the markings enumerated, are numerous others, which have been referred to Fucoides, or marine vegetation of some kind; but these are so dissimilar, that they could have been produced only by forms belonging to very different families of plants, if indeed many of them are organic at all. In regard to many of these forms, it is quite evident that they are due to inorganic or dynamic causes, and not to the influence of organization: The situation, position, association, and all other circumstances, prove them to have had this origin. Certain of these are always found upon the under side of hard layers, and always at the junction with a softer one below, a position which corresponds with that of many of the fucoides or marine vegetables. These are frequently attached to the lower side of the stratum, as if growing upon a soft bottom, and becoming imbedded in the next deposition. There are also other appearances, which seem to be due to accretionary action, by which irregular markings upon the surface of strata have been produced. Aside from these, however, are forms somewhat resembling them, which bear no marks of accretionary force; and if due to that action, it must have operated very differently from the same force in other well-defined instances. Those to which I now allude, present all the appearance of fluid mud; of such a tenacity that the current was broken, presenting several small streams, much resembling flowing cinder from an iron furnace. The surface often presents a series of interrupted semicylindrical ridges or corrugations, one behind the other, which at first view strongly impress one with the belief that they are due to some fluid body of a considerable degree of consistence.

This peculiar appearance sometimes covers only a small portion of a slab of rock, where it thins towards one side, while in others the whole surface is covered, giving the aspect of a body cast in mud, which had been irregularly scooped out by the action of shallow currents. Similar appearances are often seen in flat beaches composed of mud and sand, over which a stream of water spreads during the ebb tide. The whole surface, in such cases, is scooped into little circular hollows, communicating with one another by narrow depressions. If a deposition of sandy mud could be made upon such a surface after it had become sufficiently dry, its lower surface would present all the appearances here described as seen in many of the higher strata of New York. That such a condition may have existed, is demonstrated by other phenomena, which are proved to have happened at intervals, when the matter already deposited was near, or above the surface.

The sketch, Pl. XVII, fig. 1, represents one of these surfaces near the thinning edge of a sandy stratum,* and is one of the common appearances in the Portage group. This form, under many modifications, prevails extensively not only in the higher groups of New York, but in specimens which I have recently seen from the Connecticut River Valley, and which, Prof. Hitchcock in-

* For an analogous recent production, see Geol. Report of Massachusetts, p. 348, fig. 59.

forms me, are of frequent occurrence in the new red sandstone series.

In the strata exhibiting these peculiar appearances, I have never observed the ripple-mark, although it frequently occurs but a few feet below or above, and always within a short distance, indicating that the markings, whatever may have been their origin, were produced in shallow water, at least.

Associated with these markings is another kind, which thus far I have been unable to refer to any known cause. They consist of a series of minute parallel ridges, or extremely low terraces, not more than an eighth of an inch broad, and one quarter of this height, in truth, barely perceptible, as having this form. But from the fact of having noticed them in the Portage group of New York, and seeing the same in the collection made by Prof. Hitchcock from the new red sandstone, it seems that they were due to some cause operating in the same manner at these remote periods, and in both cases they are in conjunction with those previously described.

Casts of Mud Furrows, grooved and striated Surfaces.

The kind of markings most numerous in these rocks are the straight ridges of various lengths, which are usually referred to fucoides as their origin. There are, however, many attendant circumstances, which prove them to be the productions of a different cause. The fucoides, with no determinate general direction, are either straight or curved; they are usually short, and rarely exceed two or three feet in length. The markings in question have all a uniform direction or nearly so, and can often be traced many feet; they are round or angular, the two kinds sometimes appearing together upon the same slab. They are always upon the under surfaces of strata, being attached to a hard layer which rests upon a soft one.

In dimensions, they vary from the diameter of half a foot to that of half an inch, and we find innumerable instances where they present all the appearances of casts of striæ or shallow grooves, very much as if an impression were taken from the grooved and striated surfaces of glacial furrowed rocks.

Pl. XVII, fig. 2, represents a specimen of the kind last described, where the surface presents slight ridges, as if the deposition had been made upon a surface previously hardened to a considerable degree, and which was grooved and furrowed like the surfaces of our present rocks. It is not usual to find grooves in two directions, as in this instance.

These appearances cannot be explained by supposing a motion in the mass, by which one part was made to slide over another, for we find them at about the same position in the rock, at intervals, over a distance of twenty or thirty miles, and it must be remembered that the strata are almost horizontal, and quite undisturbed. The different degrees of hardness in the two masses in contact would prevent any such conclusion, for the lower one is too soft to impress the upper, which is the one presenting the marks. The aspect of the surface is likewise different from a grooved or striated one, the lines being in relief, lying in corresponding depressions in the shaly stratum below.

Those appearances to which I have strictly applied the term, casts of mud furrows, are straight or sometimes slightly deflected longitudinal ridges, which are found upon the lower surfaces of strata. They appear to have been originally furrows made in the mass beneath, while in a partially indurated condition, and filled with the subsequent deposit, which has preserved their form and inequalities. Some of these are deep and narrow, as if made by a heavy body dragged over the surface; others appear due to a jagged or rough-pointed surface, impressing the stone or mud, and the cast presents all these appearances.

These ridges have all a uniform direction, varying but little from northwest and southeast. This uniformity occurs in localities widely separated from each other, indicating some cause which has operated over a large area, and in a uniform manner. Oftentimes several of these ridges are seen upon the surface of a single slab, and, except in rare cases, are always parallel to each other. In a few instances I have seen several of these parallel ridges crossed by a single one at an angle of about thirty degrees, its course as regular and well defined as the others. In no case have I observed them upon the upper surface of the strata.

In a few instances I have found these ridges or casts covered with shells, which apparently were floated over the even surface, and lodged in the furrow previously made. These have adhered to the next deposition, and are now found attached to the lower surface of the same.

Pl. XVII, fig. 3, represents the section of a thin slab of this sandstone with one of these semicylindrical ridges upon its under side. On the most convex part of the ridge, at *a*, the surface is covered with small fossil shells, while the plane surfaces on either side *b b*, are entirely free from them. This would seem to indicate that the shells were floated into the furrow or depression previously existing, and there remained, the current not having power to remove them, while it swept all from the even surface to similar situations.

Such are, briefly, a few of the facts attendant upon these ridges or casts of mud furrows. I have not been able to trace any thing like organization in any of them, and their variable character, as respects form, size, and general symmetry, are strong arguments against their having had such an origin. While, on the other hand, their uniform direction, and parallelism, so essentially different from the fucoides, indicate a force that operated in one general direction, varying sometimes to the amount of a few degrees. These ridges are sometimes much larger at one end than at the other, as if the furrow which they filled was made by a heavy body grounding, and then being gradually raised and moved more lightly over the surface, and finally the impression running out entirely. In some of these casts the peculiar fractured character is apparent, as if the force making the groove had a tremulous motion. The same is seen, in some degree, in the more recent diluvial or glacial scratches. These appearances have been traced from New York as far westward as Indiana, and all possessing the general characters here described. At the same time, fucoides frequently accompany the same strata, but these can usually be distinguished from the casts.

The numerous fragments of fossils and drifted shells which accompany the same strata in many instances, sometimes forming layers of themselves, together with other circumstances, indicate a shallow ocean or a littoral position.

At some future time I hope to be able to offer to the Association the results of more extended observations. In the mean time, the object has been to call attention to the facts, in the hope that the observations of others would be directed to the same subject, and by this means new light would be thrown upon the matter, or some more satisfactory explanation given of the cause of the phenomena.

Wave Lines.

There are still another kind of markings, which are presented as minute ridges upon the surface of strata, scarcely raised above the uniform level, yet perfectly defined, pursuing no definite direction, but always more or less curved or undulating. These are not as common as the forms just described, and appear only for limited distances. The most decided and best characterized which I have seen, are in the Medina sandstone, and confined to strata forming but a small portion of this rock, appearing neither above nor below this position.

Plate XVII, fig. 4, copied from the Report of the Fourth Geological District of New York, will give an illustration. The surface, from which this is reduced, is about five feet long by three wide, being a slab quarried about one mile north of Lockport. The figure illustrates perfectly the manner in which these lines occur. From the inner side of each curve there is a slight elevation in passing outward, but which slopes gradually down to the surface beyond. I have called these markings *wave lines*, from their perfect similarity to the lines or ridges left upon sandy beaches by the retiring wave.

Any one, who has passed some time upon the bays of the ocean, bordered by almost level sandy beaches of many rods in width, will not fail to have noticed, that each retiring wave leaves behind it a small line or ridge of sand. It frequently happens, that from the ebbing tide or the lulling of the wind, each successive wave reaches less and less high up the beach; and consequently a succession of these lines is left, till the rising tide or wind brings back the water and obliterates them.

The same appearances are beautifully exhibited upon the sandy shores of our large lakes, when, towards evening, the wind dying away, leaves long beaches covered with these delicate lineations. It often happens, that during this process several successive lines are left, and then a wave larger than the rest advances and sweeps away the whole, forming a line still higher up the beach. But at the same time the wave may not reach as far laterally, and then we have the appearance of a single line in the centre, separating into several at the two extremities. This is readily conceived, if the same fact has not been observed, and it is illustrated in the wood cut.

The process by which the ridge or line is formed, seems to be this. The advancing wave, by its momentum, carries forward a small quantity of sand upon its crest; when the wave reaches its limit, the momentum being lost, and the sand being in advance, there is no force to carry it back with the retiring water, and it is thus left upon the beach marking the extreme verge of the wave. This seems to be the simple and rational explanation, where the wave is advancing directly upon the shore. When the direction of the wind is oblique to that of the shore, the wave sweeps onward, advancing upon and receding gradually from the shore; in such cases the deposition seems to take place from the centrifugal action of the wave throwing the sand beyond the limit of its power.

If from the sandy beaches of our lakes and from the sea-shore we go to the sandstone quarries, the analogy of these lines is too close to be mistaken. It leaves no doubt as to the cause. It seems as if the lake or sea beach had been converted into solid stone while yet washed by the waves, and we can almost fancy that the returning tide will obliterate them all. It is, indeed, remarkable, that these faint traces of waves should be preserved through successive layers, for many feet in thickness. How could these faint lines in the loose sand of a sea-beach have been preserved while other depositions were being made upon them? And how could the sea have retired, and again have covered the surface, leaving as it went these lines, and returning, apparently with a fresh deposit, which, on retiring again, was left marked by its retreating lines? It may not, indeed, be easy to answer satisfactorily in what manner this was done, but it seems very rational to suppose that this sandstone deposit was at that time a long, level, or nearly level sandy beach, like some upon our present sea-shore, and that the tide ebbed and flowed over this to a great distance. It may have been so nearly level, that a rise of a few feet perpendicular would cause the water to flow over many rods in breadth.

If the condition could have been that which would cause the hardening of this surface while the tide was out, the return of the wave with a fresh deposit would not obliterate the old lines, but preserve them, and in this way every fresh deposition would preserve the former lines, and in turn be marked by similar lines itself.

It is very evident, that the depositions of this period were very thin, as we find layers separated by divisional planes, and often some little foreign matter between each, which are less than one eighth of an inch thick. All these laminæ, however, are not marked by wave lines; some indicate a quiet and undisturbed condition of the water, as if the tide ebbed and flowed without wind, as was doubtless the case at times. We have thus conclusive proof of the state of this ancient ocean in regard to wind and tides, and that, like our present ocean and its bays, it was sometimes moved by winds, and at other times quiet and unruffled.

Difficult as it may be to conceive of a condition capable of preserving such minute traces of former operations as these wave lines, still we know that marks, equally liable to be erased, have been preserved through successive deposits, under what may be considered precisely similar circumstances, in great numbers, and over a great extent of country. These are the footsteps of Batrachian animals in Germany and England, and of birds in America, which are preserved through successive strata in the new red sandstone, with almost the same integrity as recent footsteps in clay, or the maker's name upon a burned brick.

The discovery of bones leaves no doubt of the origin of the footsteps in England and Germany. In the Connecticut River Valley, Prof. Hitchcock has discovered, extending through successive strata, the footsteps of birds; these, too, minute as many of them are, are still preserved in all their integrity; so much so, indeed, as to allow of specific distinctions being founded on these characters alone.

After such proofs as these, we cannot doubt the first; indeed, the one corroborates the other; and although in the wave lines we may never find other proof than that afforded by analogy, or comparison with recent effects of the same kind, yet the resemblance is so impressive, that we cannot doubt. In the case of the foot-prints, we have both analogy, and in some cases, already, demonstrative proof. In the wave lines, the analogy is equally strong as in the foot-prints, before bones had been found, which indicate an animal capable of making such impressions.

Believing that we shall be willing to admit this as a new fact in physical geology, the age of the rocks in which these marks occur, enables us to extend back, for a long period, our ideas of the time when nature operated as she now does, by winds and waves, upon the present shores; and it follows, too, that the limits of the ancient ocean did not every where extend to the great primary chain of mountains at the East.

During the last summer I have had the pleasure of reëxamining these markings upon the rocks, as well as witnessing again the effects of waves upon the sandy shores of our lakes, in company with our distinguished visiter, Mr. Lyell, and I am happy to say, that his opinion confirms what I have here stated, and encourages me to offer the facts to the notice of geologists, hoping that they may be found of interest and importance.

From the course of these wave lines we learn, that the wind was generally in the direction from the north-northwest, or varying from northwest to north, proving that the surface was higher to the southeast, for a wave line cannot be made upon a perfectly horizontal surface, although a ripple-mark may. The dip of the strata is now southward, the surface inclining in an opposite direction from what it did at the period of deposition. In the numerous specimens and surfaces which I have examined at the quarries, the direction of the wind appears to have been uniform during successive depositions. This constant direction of the wind from one quarter would indicate that there were no extensive highlands in the vicinity, as these would have more or less influenced the direction.

Throughout all the strata thus marked, there are no ripple-marks; though, in strata above and below this point, they are common, and within ten feet of the strata marked by wave lines I have seen rippled surfaces.

Notwithstanding, it is evident that this portion of the strata remained above water, or so that it was washed by the retiring tide for some length of time; yet it is equally evident, that it did not become permanently dry land. It appears more like a sand-bar, or elevated portion of the ocean bed, which might have been dry a part of the time. It should be mentioned at the same time, that this portion of the rock, thus marked, is a gray quartzose sandstone, while both below and above, the mass is a red shaly sandstone. The gray color does not appear due to any subsequent action, but to have been that of the deposit. The great horizontal extent of the mass forbids the idea, that it was due to a sudden or local phenomenon, for the numerous thin laminæ, of which it is composed, indicate a considerable period of time. It is further remarkable, that during this period there was an entire cessation of the shaly deposit, which occurs just above and below, and the coloring matter also, for the most part, ceased during the same time. (N. York Geol. Report, 4th Dist., Art. *Medina Sandstone.*)

In view of the facts first stated, if they are admitted to be substantiated, we must conclude, that denuding agencies have operated at remote periods of the earth's history, not only between great geological eras, but during the deposition of products, which form one system. The absence, in some places, of masses, which in others constitute important rocks, seems often to point to a cause of their absence in removal after deposition, rather than to thinning out from want of matter, or being beyond the reach of the transporting power. We have, in the case of the Oriskany sandstone in New York, an example of this kind, where the mass does not apparently thin gradually, but terminates abruptly, and appears beyond this point in patches, as if it had formed outliers previous to the deposition of the superincumbent masses. The evidence of its destruction is not only indicated in this way, but by the presence of rounded masses, forming pebbles upon its surface, and imbedded in the succeeding rock.

It is not in this rock alone where we have indications of removal subsequent to deposition. In the western part of New York, the strata associated with the Oriskany sandstone bear equal evidence of having been acted upon by such forces, and the result has been their partial or total destruction. In some instances, the surfaces remaining are furrowed and channelled, as by the wearing action of a powerful current, and they present inequalities similar to the rocky bed of a stream or river. In no case of this kind, however, have I been able to detect the grooved and striated surface so common on our present rocks, the general appearance and the absence of masses being the strongest ground for this inference.

In the existence of wave lines we have conclusive proof of the existence of a sea-beach at this early period of the earth's history; a period when the ocean is supposed to have held universal dominion over the surface. And, although it may not indicate any great extent of dry land, still it points to the operations which at different subsequent periods have elevated these older deposits, and to which the existence of our continents is due. These, in conjunction with the ripple-mark, the foot-print, the impression of rain-drops, furnish us with evidence, that the early condition of land and sea was, in some degree, similar to the present; at least, that tides and waves, that currents and winds were then in operation, as at present. And the existence of these phenomena points us also to other facts; for the currents were produced by inequalities of bottom, or the proximity of land, as the winds were probably due to inequalities in the surface above the ocean, and rain was only produced by mountains or high lands, which would condense the vapor.

As a class, all these phenomena adduced, aid us in determining the conditions under which deposits were actually made, while all the subsequent modifications are indicated by other phenomena. These, together with the character and condition of the fossils of the strata, may be found important auxiliaries in our investigations, and aid us in determining the great problem of the condition of the surface at remote periods, and the comparative extent of sea and land.

AN INQUIRY INTO THE ORIGIN OF THE APPALACHIAN COAL STRATA, BITUMINOUS AND ANTHRACITIC. *By Henry D. Rogers, Professor of Geology in the University of Pennsylvania, Philadelphia.*

INTRODUCTION.

THE design of the present paper is, to exhibit, in a condensed shape, some of the most characteristic phenomena of the great coal formation of the Appalachian region of the United States, to develope the laws which regulate the distribution and order of succession of the strata, and to discuss the theory of their origin. But it is not intended to embrace a detailed description of our extensive and diversified basins, a full account of which is reserved for a future opportunity.

In prosecuting this investigation, though I have relied principally on my own observations, made during several years past in Pennsylvania and Ohio, and on those of my corps of assistants, attached to the geological survey of the former State, I have received much valuable information concerning western Virginia from my brother, Professor William B. Rogers, whose researches have enabled him to test the correctness of most of my conclusions. To him, and to Mr. C. Briggs, now connected with the survey of Virginia, but formerly with that of Ohio, I am indebted for my knowledge of the range and outcrop of the great Pittsburg seam in those States; while to my brother I owe the opportunity of making a highly instructive comparison in detail, of the coal strata of Pennsylvania with those of western Virginia. For some data respecting the positions of the limestones of the Ohio coal measures, I wish to acknowledge my obligations to the laborious paper of Dr. Hildreth, in the twenty-ninth volume of the 'American Journal of Science.' I have made a similar use of the Reports of Messrs. Briggs, Whittlesey, and Foster, on the geology of the same State. My attention was first directed to the marine character of some of the Appalachian coal strata, by the description of two or three fossils from the carboniferous rocks of the Allegheny mountains, by Mr. Conrad.* Other memoirs have appeared upon local portions of the coal region of Pennsylvania, but I am not aware that their details have contributed to any of the general laws and results here presented.

Of the Limits of the Appalachian Coal Strata.

The extensive Appalachian coal formation, embraces all the detached basins, both anthracitic and semi-bituminous, of the mountain chain of Pennsylvania, Maryland, and Virginia, and also the vast bituminous trough, lying to the northwest in Pennsylvania, Ohio, Virginia, Kentucky, Tennessee, and Alabama. I shall endeavor presently to show, that all these coal-fields, extending from the northeastern counties of Pennsylvania, to the northern part of Alabama, and from the great Appalachian valley, westward into the interior of Ohio and Kentucky, include only a portion of the original formation, immense tracts having been destroyed by denudation. A comparison of the coal strata of contiguous basins, has convinced me, that they are only detached parts of a once continuous deposit; and the physical structure of the whole region most satisfactorily confirms this idea, by showing that they all repose conformably on the same rocks; the more or less insulated troughs in which they occur, merely being separated by anticlinal tracts of greater or less breadth, from which denuding action has removed the other portions of the formation. This distribution of the coal in a series of parallel and closely connected synclinal depressions, is a direct result of the system of vast flexures, into which the whole of the Appalachian rocks have been bent, by the undulatory movements that accompanied the final elevation of the strata, and terminated the era of the coal.

Many of the general phenomena about to be described, seem to belong, in an equal degree, to the wide coal basins of equivalent age, which lie remote from the Appalachian chain, far to the northwest, namely, that of the State of Michigan, and that which occupies a part of Indiana, Illinois, and Missouri. I shall

*See Trans. Geo. Soc. of Pennsylvania, 1835.

confine my views for the present, however, to the formation as it is developed in the mountain basins, and in the great trough or plain which lies immediately to the northwest of the chain. This last, most western, or chief Appalachian basin, terminates on the northeast, near Towanda, in Bradford county, Pennsylvania, while its southern point is near Huntsville, in Alabama. The southeastern margin coincides nearly with the main escarpment of the Allegheny mountain, as far south as the county of Hardy, in Virginia, beyond which it lies further to the northwest, following as it ranges through that State, and through Tennessee, the great line of escarpment locally named Laurel Hill, Rich mountain, Little Gauly mountain, Great Flat Top, and Cumberland mountain, ending with the termination of the last in northern Alabama.

The opposite or northwestern outcrop, commencing likewise at Towanda, extends nearly westward through the northern counties of Pennsylvania to the Allegheny river, at Warren. It here begins to curve gently southward, passing through Crawford and Mercer counties, and enters Ohio north of Sharon. Beyond this its general course is about west-southwest to Akron, where it deflects to the south, so as to pass about twenty-five miles west of Zanesville, after which it crosses the Ohio river a few miles above the mouth of the Scioto. Southward from this point the western line of the coal traverses Kentucky in a south-southwest direction, passing the Kentucky river near the centre of Estil county, and the Tennessee line a little east of Rock creek. Ranging through Tennessee, its course is rather irregular, first running southward to Montgomery, thence northwestward to Morgan, and thence by a winding line southward to Sparta, beyond which it stretches southwestward to the termination of the Cumberland mountain, northeast of Huntsville.

This enormous tract of the coal formation is unbroken, except in two quarters; first, near its northeastern termination, and along its northern border in Pennsylvania, where by the influence of denudation, and a few low anticlinal arches, many small patches of the strata lie insulated from the general mass; and, secondly, along its southeastern side in Pennsylvania, Maryland, and Virginia, where a few bold axes of elevation have thrown the coal rocks into a series of long, parallel, and nearly united troughs. Considering all of these outlying portions of the formation as subordinate and intimately connected parts of one great bituminous coal-field, the southeastern boundary of which is the escarpment of the Allegheny and Cumberland mountains, the dimensions of the great basin will be nearly as follows: Its length, from northeast to southwest, is rather more than seven hundred and twenty miles, and its greatest breadth about one hundred and eighty miles. Upon a moderate estimate, its superficial area amounts to sixty-three thousand square miles.

There are besides this, however, several smaller basins which lie to the southeast, and are entirely separated from it. These consist of the detached troughs of anthracite, in eastern Pennsylvania, and the solitary outlying basin of semi-bituminous coal in Broad Top mountain, near the Juniata river. The total area of the coal strata in the anthracite district, may be approximately stated at about two hundred square miles, while the semi-bituminous formation of Broad Top is comparatively limited.

Though the deep anthracite basins abound in curious structural features, and contain thick seams of coal, they chiefly interest us at present, by the geographical position which they occupy. More than forty miles distant from the general denuded margin of the main or western coal-field, they nevertheless present, in the character of their strata, and of the rocks upon which they repose, unequivocal evidence that they and the bituminous basins were once united. In this identification, we are presented with an amazing picture of the former extent of our carboniferous deposits. The existing southeastern limit of the coal, in these insulated basins, lies, in Pennsylvania, only a short distance to the northwest of the great Appalachian valley, and a survey of all the circumstances involved in the question of the ancient physical geography of the formation, convinces me that it extended, both in that State and Virginia, at least as far to the southeast as that valley. To enter here into all the facts and reasonings upon which this inference is founded, would lead me aside from the main purpose of the present paper; but I may mention, as one argument, that a group of coal strata, somewhat lower in the formation than the main series, does reach, at intervals, as far eastward as the margin of the great valley, in a number of localities between the Potomac river and the Tennessee line. Restricting our attention, at present, however, to those districts where the main coal series is developed, we meet with the most ample proofs that all the strata in the insulated basins are precisely on the same geological horizon, as those of the great basin west of the mountains. These coal rocks all repose conformably on the same easily recognized formation, the great coal conglomerate, with the upper beds of which the lower seams are very generally interstratified. This fact, but more especially the circumstance that I have traced many of the principal coal seams and beds of fossiliferous limestone from basin to basin, fully demonstrates that all these detached troughs, however insulated and remote from the main mass at present, were, at the period of their deposition, united in one continuous formation, which, previously to its elevation and waste by denuding currents, extended from nearly the eastern side of the Appalachian chain, to a western margin, at least as distant as the centres of the States of Ohio, Kentucky, and Tennessee.

Here then we have a coal formation, which, before its original limits were reduced, measured, at a reasonable calculation, nine hundred miles in length, and in some places more than two hundred miles in breadth. I would ask, is it conceivable, that any lake, bay, or estuary, could have been the receptacle of a deposit so extended, or that any river or rivers could have possessed a delta so vast? The ancient Appalachian ocean grew deeper, as I shall show, towards the west or northwest, and inasmuch as rivers push their deltal deposits seawards, and not laterally, and as the carboniferous sediments here to be described are traceable coastwise, as respects this ancient sea, for a length of nine hundred miles, it is inconceivable how any local fluviatile currents could have assembled them.

My chief object in the present memoir being to exhibit the leading phenomena, which bear immediately on the discussions connected with the origin of this and other coal formations, I shall not here attempt a minute description of all the carboniferous rocks; and, to confine these remarks within as small a compass as possible, I shall restrict them to the main or upper coal measures, since these are the beds which best display the physical conditions under which the strata were accumulated.

Nature of the Coal Strata.

Assuming it as susceptible of demonstration, that all the various coal basins, bituminous and anthracitic, of Pennsylvania, Ohio, Maryland, Virginia, Kentucky, and Tennessee, were, as above stated, originally united, we may consider the whole as one great formation, in which some highly interesting gradations in the type and composition of the beds may be traced. To call attention to these phenomena of variation is indeed the main object of this paper, since by them only can we arrive at a true theory of the conditions under which the whole were formed. A comprehensive classification of the strata, shows the following principal varieties.

1. Rocks of mechanical origin, of every grade of coarseness, from the smoothest fire-clay, to exceedingly rough siliceous conglomerates, the whole including within these extremes a wide variety of shales, marls, argillaceous sandstones, and quartzose grits.

2. Limestones, both pure and magnesian, in strata of all thicknesses, from thin bands and narrow layers of detached nodules, to beds measuring from fifty to one hundred feet in depth. Some of the limestones contain a considerable amount of argillaceous and siliceous matter, and many of the thicker deposits consist of alternating layers of limestone and soft shale. Though a few of these calcareous strata are remarkably destitute of fossils, they are rarely found to be altogether deficient in organic remains, when widely and diligently searched; and some of them quite abound in them. It is especially deserving of note, that the genera are such as invariably indicate oceanic habits. This fact is of the more importance, since some of the limestones occur in immediate contact with beds of coal, and with shales and other strata containing the remains of terrestrial vegetation.

Besides the strata of limestone, we meet with other chemically formed deposits, in the form of numerous seams of carbonate of iron, and a few considerable beds of regularly stratified chert. The nodular variety of the iron ore is usually imbedded in shale, and lies oftenest adjacent to the coal, while the ore in bands occurs more frequently in contact with the limestone.

3. Coal, in nearly all its known varieties, including every description, from the dryest and most compact anthracites, to the most fusible and bituminous kinds of common coal.

Such are the three great classes of strata, comprised within the Appalachian coal region of the United States. If we direct our attention to the manner of their distribution, we shall behold some striking and instructive phenomena, susceptible of reduction to regular and harmonious laws of gradation.

Comparing, in the first place, the rocks of mechanical origin, as they occur in different districts, we almost invariably find them coarsest and most massive towards the southeast, and more and more fine-grained and less arenaceous, as we pursue them across the successive parallel basins northwestward. Thus in the anthracite coal-fields, which are the most southeastern of all, the coal is interstratified with a vast thickness of rough and ponderous grits, and coarse siliceous conglomerates; but is associated with comparatively very little soft clay slate or shale. In this region, the coal slates themselves, are more than ordinarily arenaceous, and bear a smaller proportion to the sandstones, than in the basins more to the west. At the same time that the coal rocks, viewed in the aggregate, acquire a finer texture, in going westward, the individual strata undergo a corresponding reduction in thickness, while many of them entirely thin away. I may cite, as a striking instance of these changes, the great coal conglomerate itself, which forms the general base of the main or upper coal measures. This massive rock is chiefly composed of large quartzose pebbles, imbedded in coarse sand. Adjacent to its most southeastern outcrop in Pennsylvania, that is to say, in the Sharp Mountain, where it constitutes the boundary of the first or Pottsville basin, it has a thickness of nearly fifteen hundred feet; but in the mountains which embrace the Wyoming coal-field, about thirty miles to the northwest, the thickness of the formation is only about five hundred feet; while still further across the chain, where it becomes the general floor of the coal measures under the bituminous form, in the basins northwest of the Allegheny mountain, its entire thickness seldom exceeds eighty or one hundred feet. Tracing it across the great western coal-field, until we encounter its last outcrop in western Pennsylvania, Ohio, and Kentucky, this wonderfully expanded rock, dwindles to a thin bed of sandstone, sprinkled with a few pebbles, its whole thickness amounting generally to only twenty or thirty feet. There is a corresponding and quite as striking a diminution in its constituent fragments, the pebbles in the most southeastern belts of the formation being often as large as a hen's egg; while in the northwestern, their diameter is reduced to that of a pea.

A similar gradation obtains in the thickness and coarseness of nearly all the interstratified sandstones and other mechanical members of the formation. I conceive that this interesting fact, fully established by the surveys of Pennsylvania and Virginia, shows beyond all question, that the southeast was the quarter whence the coarser materials of the coal rocks were derived. But there are not wanting other proofs that the ancient land lay in that direction. These will be presently detailed in describing the gradations witnessed in the limestones and beds of coal. The above general law of distribution, relates, it should be observed, only to the coarser mechanical aggregates, since there are some apparent exceptions to its generality, among the finer-grained slates and shales. Though the texture of these continues to grow finer as we advance westward, some of the strata, when individually traced, seem to increase for a certain distance in thickness. This curious circumstance, which belongs indeed to many of the more argillaceous members of our Appalachian formations, so far from invalidating the above inferences respecting the westward transportation of the sediments, comes beautifully to confirm them, since it is evident, that until a current, holding in suspension a quantity of sedimentary matter, declines in velocity to a certain point, it cannot let fall any considerable amount of the smaller particles. After it has reached a given degree of retardation, the finer materials will subside, and in an increasing quantity, up to a certain point, at which the loss of velocity in the current is compensated by the exhaustion of material, when a gradual and final thinning of the deposit will take place.

If we examine, in the next place, the gradations of thickness visible in the limestones and other marine deposits, they will be found to lead to precisely similar inferences respecting the position of the ancient land. Viewed either together or individually, the limestones of the coal-measures of Pennsylvania, Virginia, and Ohio, display a remarkably uniform augmentation, as we trace them westward. Thus, throughout all the southeastern basins, comprising the whole of the anthracite coal-fields of Pennsylvania, and the Broad Top mountain in the same State, the formation exhibits a total absence of limestone, and a corresponding deficiency of calcareous matter in the shales and the iron ores. Advancing, however, a distance of twenty-five or fifty miles northwestward, to the general southeastern margin of the great bituminous region, where we enter on the first of the chain of partially insulated troughs adjacent to the escarpment of the Allegheny mountain, we no longer encounter a total poverty of limestone, though we still meet with a striking deficiency. As an evidence of this, let us take one of the basins of the Allegheny mountain, that, for example, which lies near the head of the Potomac river. The minute researches there made, in connection with the geological surveys of Virginia and Pennsylvania, have shown that the total thickness of the limestones, counting all the thin bands and layers of nodules, does not probably exceed ten feet. This statement is confirmed by a pamphlet on the same coal-field, describing the land of the George's Creek Company, by Messrs. Alexander and Tyson. In their very full section of the strata, we do not see a single band of limestone introduced.

Turning to the Moshanan basin, in Centre county, which is also a marginal trough of the great western coal-field, the entire quantity of limestone appears to be about seven or eight feet. If, however, we pass westward from this southeastern line, and cross the great coal-field by any section, between the Susquehanna in Pennsylvania, and the Little Kenawha in Virginia, we witness a regularly progressive expansion of the calcareous rocks. In the following tabular statement, which refers chiefly to the southern counties of Pennsylvania, this gradation is rendered strikingly obvious.

TABLE FIRST,

Showing the gradual Increase in the aggregate thickness of the Limestone, as we cross the Southern Coal-fields of Pennsylvania, westward.

Broad Top basin; half way across the Appalachian chain, ...	*none.*
Potomac basin; near the main escarpment of the Allegheny mountain,	about 10 feet.
Eastern basin of Somerset county, west of the escarpment, and about twelve miles west of the Potomac basin, ...	12 feet.
Ligonier basin, twenty miles west of the last, ...	30 feet.
Second western basin, on the Youghiogheny river, fifteen miles west of the last, ...	about 40 feet.
Great basin of the Monongahela and Ohio rivers, at Brownsville, probably,	60 feet.
Same basin at Wheeling, ...	about 200 feet.

The above aggregates admit the more accurately of comparison, since most of them refer to the same portion of the formation, that, namely, which is included between the great conglomerate, and the top of the main limestone, above the Pittsburg coal-seam.

TABLE SECOND,

Showing the Gradation in the thickness of the large Limestone stratum, overlying the Pittsburg Coal-seam.

Cumberland basin; not more than	2 feet.
Eastern Somerset basin, not determined, but	thin.
Ligonier basin,—average about	7 feet.
Monongahela and Ohio basin, at Brownsville, ...	41 feet.
Same basin at Wheeling, ...	54 feet.

In the upper coal group, or that part of the series which commences with the Pittsburg seam, the total thickness of pure limestone, excluding numerous thin bands, associated with some of the layers of shale, is not less than one hundred and fifty feet.* Some of the limestone strata of the coal-measures, possess, as will be seen from the second of these tables, a remarkably wide dis-

* See Report on Geological Survey of Virginia, for 1840.

tribution, ranging without interruption from the vicinity of the Allegheny mountain, to the country west of the Allegheny river. Having ascertained the positions of a number of these fossiliferous beds, I am now engaged in investigating their organic remains. The examinations already made, show that these all belong to *marine* genera, and that the different beds are characterized by their peculiar species. Many of these beds of limestone have been traced continuously from northern Pennsylvania to the Kenawha, and from the eastern outcrop, near the Allegheny mountain, to their western boundary in Ohio. The marine character of their genera, — *Terebratula*, *Goniatites*, *Bellerophon*, *Encrinus*, &c., sufficiently proves that these rocks were originally deposited beneath the waters of an ocean, while at the same time the increasing purity of the limestones, and the multiplication and expansion of the beds westward, clearly show that the ancient ocean augmented regularly in depth in that direction. This conclusion, it will be observed, agrees strictly with the results before deduced from the general gradation, visible in the sandstones and other mechanically formed rocks, which proves that the ancient land was situated towards the east or southeast. If we examine the relations of the two classes of the coal-strata to each other, the land-derived and sea-derived rocks, we perceive that the latter, or the limestones, thicken, going west at the expense of the former. Frequently, two beds approach, and either entirely coalesce, or remain divided by only a thin, marly shale, formed from the residual, finely subdivided matter, wafted out by the currents, which, further eastward, or nearer the land, deposited the coarser and thicker sandstones and arenaceous slates. While this gradation shows itself, new beds of calcareous rock interpolate themselves in new positions in the series, and many of the sandstones thin away and cease altogether, so that the whole formation becomes, by both these changes, more and more oceanic in its type. But the most important result of this mode of tracing the strata, is the evidence we have of the frequent alternation of a tranquil and disturbed condition of the waters. Such an intermission of movement and repose will be more fully proved, when I come to describe the phenomena connected with the coal-seams. It may be sufficient here to refer to what I have above stated, respecting the oceanic and shore rocks, and to appeal to the argument that the coarser or more irregularly strewn the materials of a stratum are, the more violent must have been the current which transported them. With these considerations before us, we cannot fail to perceive, in the Appalachian coal-strata, the monuments of many alternate periods of movement and total or comparative rest. If it be conceded, that each of the purer beds of limestone, remarkable for the extreme fineness of their texture, and the absence of foreign sedimentary matter, is the index of a longer or a shorter interval of tranquillity in the waters, we shall discern (omitting for the present all similar inferences to be derived from the coal-seams) a much greater number of such separate periods, than a mere enumeration of the individual beds would indicate, unless we attend to the interstratified shales and marls. These last-mentioned strata, generally assuming, as we go eastward, a thicker and coarser type, furnish as unequivocal a record of disturbances, as if the spaces they occupy between the beds of limestone, were filled by the coarsest mechanical aggregates.

One of the most interesting general questions connected with the land and sea-produced strata, relates to the physical geography of the ancient coast, near to which they were deposited, and the inquiry at once suggests itself, whether the receptacle of these various sediments was an extensive estuary, receiving the silts of some gigantic river or rivers, or a vast expanse of shallow sea, bounded by a long line of coast, upon which the successive deposits were formed by a very different agency from any we can ascribe to ordinary fluviatile or littoral currents.

Of the Phenomena connected with the Coal-Seams.

Great extent of certain individual coal-beds. Passing, in the next place, to an examination of the most interesting portion of the coal strata, the coal-seams themselves, we discover in the facts connected with their range and distribution, in the structure of the coal, and in the nature of the beds in immediate contact with the seams, several general laws, tending to afford us a still better insight into the physical conditions which accompanied the production of these strata.

Of the facts connected with the range of the individual coal-seams, that of their prodigious extent is, itself, one of the most surprising and instructive. As a general rule, this wide expansion characterizes all the beds of both the bituminous and anthracitic basins. It is true, that many seams possess a comparatively local range, but not a few of those which, on first examination, appear of circumscribed extent, cover in reality a very wide area, the error respecting them being caused by fluctuations of thickness, or by their occasionally thinning out and reappearing. Among those which manifest great permanency as to thickness, the vast range of some of the larger ones is truly extraordinary. Let us trace, for example, the great bed, which occurs so finely exposed at Pittsburg, and along nearly the whole length of the Monongahela river, and which I have called the Pittsburg seam. The high position which this bed occupies in the formation, and the nearly horizontal attitude of all the strata, combine to expose it very extensively to observation, while its great size, and the excellence of the coal, have caused it to be generally mined. After identifying and tracing it from basin to basin in Pennsylvania, I have been furnished with much information in relation to its limits and features in Virginia and Ohio, by my brother and Mr. Briggs. Guided by the data thus collected, I have been enabled to determine its area and boundaries with very considerable accuracy. The limits of this bed, as at present known, are nearly as follows. That portion, by far the largest part, which is contained in the great western basin, has its northern termination in Indiana county, in Pennsylvania, and its southwestern on the Ohio river, below Guyandotte. The general southeastern outcrop ranges along the western foot of the Chestnut ridge, or West Laurel hill, from Indiana county to Tygart's river, in Virginia. It here alters its strike from south-southwest to a direction more nearly south, passing a little west of and parallel to, Buchanan's river, until it nearly gains the head-waters of the Monongahela. From this point its course is more winding, but the general direction is a little west of southwest to the Great

Kenawha, which it crosses between Charlestown and the Pocatalico creek. From the Kenawha, it ranges nearly west to the Ohio river, between Guyandotte and Burlington, where, crossing that great stream into the state of Ohio, it sweeps rapidly north. Its outcrop, now following the western margin of the basin, preserves a general north-northeast direction as far as McConnelsville, on the Muskingum. Beyond this point it stretches in a northeasterly course, until it recrosses the Ohio river a little above Steubenville, where it soon reaches the western line of Pennsylvania, in Beaver county. Here the edge of the seam turns eastward, and crosses the Ohio river once more, a few miles below Pittsburg, and the Allegheny river, some miles northeast of that town. East of this point, it pursues a more devious line, the meanderings of which are caused by three parallel anticlinal axes, crossing the Kiskiminitas and Conemaugh rivers. Being thrown into a very irregular and curving outcrop by these elevations, it finally joins the southeastern margin, at the northeast extremity of the basin, in Indiana county, the point from which we set out. The longest diameter of the great elliptical area here delineated, is very nearly two hundred and twenty-five miles, and its maximum breadth about one hundred miles. The superficial extent of the whole coal-seam, as nearly as I can estimate it, is about fourteen thousand square miles.

But the limits here described, though wide, fall very far within those which the bed anciently occupied. To the southeast of the large basin of the Ohio river, there are several other insulated, parallel troughs, which also contain the Pittsburg seam. Of these, the furthest from the main coal-field is that at the head of the Potomac river, at a distance of about forty-three miles in a straight line. The eastern margin of the Pittsburg bed is here, however, nearly fifty miles east-southeast of the eastern edge of the same seam, in the main or western basin, and it has a corresponding expansion eastward, in other districts. That this coal-bed preserves an unbroken range for many miles to the northeast of the termination of the principal basin, in Indiana county, appears highly probable, from a comparison of the coal-measures at certain localities in that quarter. I shall not, however, assume the known length of the tract actually occupied by it, as exceeding the above-mentioned two hundred and twenty-five miles, throughout which it is uninterruptedly traceable. If we now take into account the fifty additional miles of breadth which the bed once possessed, its former area must have been at least thirty-four thousand square miles, a superficial extent greater than that of Scotland or Ireland.

Though the above is, perhaps, the greatest extent of surface, which it is in our power positively to assign to this bed of coal, the proofs of a prodigious denudation of the strata, throughout the districts bordering its present outcrop, are so irresistible, that I consider the dimensions here given as bearing actually but a small proportion to the real ancient limits of the stratum. I consider it, indeed, probable, that this seam is identical with the great bed which occurs in all the anthracite basins, and which displays a similar degree of constancy in its features. Opportunities for research have not yet occurred to enable me, however, to produce evidence as to this point, of a sufficiently conclusive character. Should such an identity be established, we shall then behold, in all its conditions of gradation from anthracite to semi-bituminous and highly bituminous coal, a single stratum, measuring, at the most moderate calculation, four hundred and fifty miles in length, and two hundred miles in breadth, and covering a space of at least ninety thousand square miles. But, restricting our attention for the present to those limits, which it did undoubtedly once occupy, it is still by far the most extensive coal-bed yet explored in any country, and the mere fact of its great extent must exert an influence on our views concerning the conditions under which the whole coal-formation originated.

The general uniformity in the thickness of this superb bed, throughout so vast a region, and at the same time the regular and gentle gradation which it experiences in size, when we trace it from one outcrop to the other, are features not less remarkable than its enormous length and breadth. In the most southeastern basins, where it is most developed, its total thickness is from twelve to fourteen feet; while in the basins between the Chestnut ridge and the Monongahela river, it usually measures from ten to twelve feet. Still further to the west, between the Monongahela river at Brownsville and the Ohio at Wheeling, it declines from about ten to eight feet, and beyond this, in the state of Ohio, it seldom exceeds five or six feet. Following it longitudinally, or in the direction of the great elliptical basin, it displays quite as remarkable a persistency in its dimensions, the reduction in its size being, if any thing, still more gradual from northeast to southwest. Thus at Pittsburg it measures, altogether, about eight feet; at the mouth of Big Grave creek rather more than five; on the Great Kenawha about five; and from this point to Guyandotte, where it terminates, three feet; and, finally, hardly two feet. Tracing it along a parallel line, from northeast to southwest, but nearer its southeastern outcrop, we detect the same very gradual abatement in its thickness. While we are thus furnished with conclusive evidence, from the fact that its rate of increase is most rapid towards the southeast, that the ancient land with which the stratum was connected must have been situated in that direction, we see that the northeastern part of the coast was the quarter where its materials were supplied in the greatest abundance. To this conclusion I am disposed to appeal, in support of the conjecture already ventured, that this great bed of the main or western coal-field, is but a remnant of a still more expanded stratum, which attained its maximum size, in the enormous seam of which all the anthracite basins present us insulated patches. The singular constancy in the thickness of this Pittsburg bed, no less than its prodigious range, are circumstances that seem strongly adverse to the theory which ascribes the formation of such deposits to any species of *drifting* action. But a more thorough discussion of this question will be attempted presently.

Of the intimate Mechanical Structure of the Coal.

An examination of the structure of the coal itself, apart from the fact of the great range and uniformity in the thickness of the beds, renders it apparent, that no irregular dispersion of the vegetable matter by any conceivable mode of drifting, either into estuaries, or the open sea, could produce the phenomena which they exhibit. The mechanical arrangement of the layers in every coal seam, as seen when viewed edgewise, indicates plainly, that it is a compound stratum, as much as any other sedimentary deposit, each bed being made up of innumerable very thin laminæ of glossy coal, alternating with equally minute plates of impure coal, containing a small admixture of finely divided earthy matter. These subdivisions, differing in their lustre and fracture, are frequently of excessive thinness, the less brilliant leaves sometimes not exceeding the thickness of a sheet of paper. In many of the purer coal-beds, both anthracitic and bituminous, these thin partings between the more lustrous layers, consist of little laminæ of pure fibrous charcoal, in which we may discover the peculiar texture of the leaves, fronds, and even the bark of the plants which supplied a part of the vegetable matter of the bed. If traced out to their edges, all these ultimate divisions of a mass of coal will be found to extend over a surprisingly large surface, when we consider their minute thickness. Pursuing any given brilliant layer, whose thickness may not exceed the fourth part of an inch, we may observe it to extend over a superficial space which is wholly incompatible with the idea, that it can have been derived from the flattened trunk or limb of any arborescent plant, however compressible. When a very large block of coal is thus minutely and carefully dissected, it very seldom, if ever, gives the slightest evidence of having been produced from the more solid parts of trees, though it may abound in fragments of their fronds and deciduous extremities. The laminæ of brilliant carbonaceous matter almost invariably thin away to a fine edge before they terminate, a fact which of itself seems to prove, that the material was in a soft or pulpy state at the time of its accumulation, and this supposition receives countenance from the homogeneous texture and conchoidal fracture of every such layer.

Granting the correctness of this inference, which is not in conflict with the beautiful microscopic determinations, by Hutton, respecting the traces of vegetable structure in certain portions of coal, the argument seems almost conclusive, that the vegetable matter grew where it was deposited. It is difficult to understand why the coal should not consist, principally, of the larger parts of trees, such as their trunks, limbs, and roots, if any species of drifting operation brought together the materials of the bed, by conveying seawards the growth of ancient forests. The leaves, and other fragile parts, would soon become detached on the voyage, and these, together with the smaller plants, would subside and get imbedded, long before the trunks and lighter woody parts could grow sufficiently water-logged to sink. It is obvious, that a stratum formed by the successive deposition of huge irregular stems and branches, would exhibit, no matter what might be the subsequent pressure, a very different structure from that thin and uniform lamination, which distinguishes all beds of coal. These considerations, derived from the mechanical features of every seam of coal, receive strong confirmation from the microscopic researches of Mr. Hutton. Though that observer found more or less of the cellular vegetable structure in each of the three varieties of Newcastle coal, he discovered a complete obliteration of the characteristic cells in those finest lustrous portions of the caking coal, where the crystalline structure, as he terms it, is best developed. Besides the above-mentioned features, all the coal-beds which I have ever examined or seen minutely described, possess another peculiarity in their mechanical constitution, on a less minute scale, which is equally incompatible with the notion of a transportation by currents. I refer here to the subordinate divisions of the coal-beds, some of which are strata of pure coal, some of earthy coal, and some of common shale, all constituting together the compound mass, which we call a coal-seam, but each maintaining its particular position and character as a distinct deposit over an area which is truly astonishing. Those persons who are conversant with large mining districts are aware of the many instances of remarkable persistency in these subdivisions in the coal-beds, since it is frequently by their means that the miners recognize a known coal-seam in cases of difficulty. Thus the largest bed of the anthracite fields of Pennsylvania contains, almost every where, a particular band of unusually pure coal, not far from the bottom, generally from three to four feet in thickness. A still more striking example occurs in the great Pittsburg bed, already spoken of. If we dissect this compound mass, and trace the several divisions, we become impressed with the wonderful distances to which some of them extend. Not to enter here into a minute discussion of all the features of this widely distributed seam, it will suffice to state, that it consists principally of three members, which are readily recognized. The lowest is a thick bed of uncommonly pure coal, the middle a layer of soft shale or fire-clay, about one foot in thickness, and the uppermost or roof coal is itself a compound seam, two or three feet thick, of alternating layers of coal and fire-clay. Now it is a highly instructive fact, that this general triple subdivision prevails throughout nearly the whole range of the seam from its eastern to its western outcrops, and from the Conemaugh, in Pennsylvania, into Western Virginia, for a distance of more than two hundred miles, from northeast to southwest. But besides this fact, each subordinate portion preserves its own distinctive features, the upper member being every where remarkable for its alternation of thin bands of coal and shale. Can any evidence be more conclusive as to the uniformity of the conditions under which every part of this coal-bed was produced? There must, indeed, have prevailed an almost perfect uniformity in the state of the surface throughout the vast area which it occupies, as respects even the formation of the thinnest of these subdivisions. Such remarkable sameness of action throughout the same geological horizon, appears absolutely incompatible with any mode of drifting of the vegetable matter. Only one particular process of accumulation promises to explain the occurrence in such cases, of these thin and uniform sheets of material, of which the thickness is often less than a foot, while their superficial area is many hundred square miles. I cannot conceive any state of the surface, but that in which the margin of the sea was occupied by vast marine savannahs of some peat-creating plant, growing half immersed on a perfectly horizontal plain, and this fringed and interspersed with forests of trees, shedding their offal of leaves upon the marsh. Such are the only circumstances, under which I can imagine that these regularly parallel, thin, and widely extended sheets of carbonaceous matter, could have been accumulated.

Independently of the above argument, based on the breadth and uniform distribution of the layers in the coal, there is another, drawn from the striking deficiency of earthy sedimentary particles. In many of the purest layers, the total proportion by weight of foreign mineral substance, in the coal, is less than two per cent., sometimes barely one per cent., while the ratio by bulk is consequently less than one half of this. So extremely insignificant a quantity is what we should expect, on the hypothesis of a tranquil accumulation in wide sea-meadows, extending far out from the edge of the ancient shore, where no turbid currents could get access. It is as inconsistent, on the other hand, with the notion of a drifting of the vegetable matter itself, which, according to any conceivable mode of transportation, would be accompanied by a large amount of earthy matter, such as abounds in all deltal deposits, and even mingles with the wood in the raft of the Atchafalaya. That so nearly the whole of the suspended mineral matter, even to the fine particles of impalpable clay, should have subsided, in almost every instance, before the first portions of the floating vegetation sank, contradicts all observation respecting similar actions now occurring. The introduction of any argillaceous matter into the transparent waters of the great peat morasses, must have happened in the manner of an exceedingly quiet and diffused silting in, or more properly a slow intermingling, of very slightly turbid water with that of the limpid sea. The above arguments from the uniformity in the distribution of the vegetable matter of the coal-seams, and from the absence of earthy matters in the coal, have been already employed by Mr. Beaumont as objections to the drift theory, in a communication read to the Geological Society of London, February 26th, 1840.*

Of the Character of the Strata in immediate contact with the Coal-Seams.

Turning from the structure of the coal itself, to the character of the strata, usually in immediate contact with it, we discover certain prevailing relations, from which, by a careful study, much

* Beaumont, Proceedings Geol. Soc., No. 69.

light is to be derived both as to the statical conditions, and the order of the physical events which attended the production of the whole coal-formation. There is an interesting and characteristic difference, in point of composition and structure, between the beds bounding the upper and lower surfaces of every coal-seam. This, though of great significance in its bearings on the theory of the formation of coal, has never been distinctly examined with that view.

Of the material underlying the coal-beds. The deposit, upon which each seam of coal immediately rests, and which I shall call the floor, is, with a few rare exceptions, wholly distinct in its composition from the roof, or that which reposes directly upon the bed. To Mr. Logan we are indebted for having ascertained the highly important fact, that the floor of every coal-seam in South Wales is composed of a peculiar variety of more or less sandy clay, distinguished by its containing the *Stigmaria ficoides.* "Portions of the stem of the *Stigmaria* are found in other parts of the coal-measures, but it is only in the under clay, that the fibrous processes are attached to the stem, or associated with it." * Since the publication of his Observations on the Stigmaria Beds of South Wales, the same gentleman has extended his researches to the United States, and has found our own coal-seams in Pennsylvania to be similarly accompanied.† Mr. Lyell has also shown, that this peculiar stratum underlies the bituminous coal-beds at Blossburg, in Pennsylvania. I subsequently visited, with that eminent geologist, the anthracite beds of the Pottsville and the Beaver Meadow basins in Pennsylvania, where we found the Stigmaria bed, in the same position, below those seams. Still more recently, I have ascertained from my own notes on the geological survey of Pennsylvania, and from those of my brother in relation to Virginia, that this deposit accompanies nearly every coal-bed in the great bituminous region west of the Allegheny mountain. I shall take occasion presently, however, to point out some peculiar exceptions to its general prevalence. The theoret-

* Logan, Proceedings Geological Society, No. 69.

† Logan, Proceedings Geological Society, for April, 1842.

ical importance of this generalization concerning the Stigmaria, and the fire-clay inclosing it, appears to have been discerned by Mr. Logan, but he has not offered any explanation of the fact. The following passage, from the published abstract of his paper, conveys his views: "When it is considered, that over so considerable an area as the coal-field of South Wales, not a seam has been discovered, without an under-clay abounding in Stigmaria, it is impossible to avoid the inference, that there is some essential and necessary connection between the existence of the Stigmaria and the production of the coal. To account for their unfailing combination by drift, seems unsatisfactory; but whatever may be the mutual dependence of the phenomena, it affords reasonable grounds to suppose, that the *Stigmaria ficoides* is the plant to which we may mainly ascribe the vast stores of fossil fuel." I am not aware, that either Mr. Logan, or any other geological writer, has attempted to account for the great frequency of this stratum immediately underneath the coal, or that any hypothesis has been advanced to explain the general prevalence in it of the Stigmaria, and the absence of all those other species of plants, which abound among the layers of the coal itself, and in the roof, and other overlying rocks. One main object of the following theory of the origin of the coal-measures, is to attempt the solution of these curious facts:*

* Since this memoir was written, my attention has been called by my brother, Prof. Wm. B. Rogers, of Virginia, to the splendid work of Mr. Edward Mammatt, on the Coal-Field of Ashby de la Zouch, published in 1834. This elaborate description contains a clear announcement of an under-clay for almost every coal-seam, and mentions, moreover, the presence "of a distinct single vegetation" in that of the *main coal*, with other facts and suggestions, since confirmed by Mr. Logan, and several other recent writers, on the origin of the coal strata. I cannot find, that the obvious claims of Mr. Mammatt to priority, as a discoverer in this interesting subject, have been any where acknowledged. It is to be regretted, that the still earlier opinions of Werner, De Luc, and Adolph Brongniart, attributing the vegetable matter of the coal-beds to a growth on the spot where the coal now exists, should have escaped so generally the attention of British geologists, with the exception of Mr Lyell.*

The following passages, from Mr. Mammatt's work, will convince us how very near he was to a clear conception of the relations of the Stigmaria, and to a sound doctrine of the circumstances, under which the coal-beds were accumulated. "Seams of fire-clay abound in the Ashby coal-field, and there are very few coal-measures (coal-seams?) which

* Since this paper was read, Dr. Buckland's admirable 'Anniversary Address to the Geol. Society of London, for 1841,' has appeared; in which he mentions, that this doctrine has been entertained by De Luc, McCulloch, Jameson, Brongniart, Lindley, and other writers.

The Stigmaria presented in its structure, according to Lindley and Hutton, a low, dome-shaped, fleshy trunk, or centre, from the edge of which there radiated a number of horizontal branches, supplied with a multitude of slender, cylindrical, and exceedingly long leaves. The fire-clay, or Stigmaria clay, as we may indifferently call it, abounds in these delicate leaves, in a flattened and distorted condition; and it is partly to them and partly to the comminuted state of the argillaceous material itself, that the stratum owes its characteristic tendency to crumble in every direction. The branches of the Stigmaria, which usually lie parallel to the plane of the stratum, and are most abundant nearest the coal, it has been suggested, were hollow cylinders, composed entirely of spiral vessels, and contained a thick pith. The plants, according to Dr. Buckland, probably floated on the water.

Of the Roof of the Coal.

If we examine, in the next place, the strata which immediately rest upon the coal, we shall discover a condition of things in striking contrast with the phenomena of the under-clay. Instead

do not rest upon it, as the Sections will show." And again. " From the circumstance, that so many cases occur, where a tolerably pure fire-clay lies immediately under, and in contact with, a bed of coal, it may be inferred, that such clay stratum could not have been the soil, where grew the vegetable matter which produced the coal, unless this vegetable matter was a moss, a peat, or some aquatic plant; because, in the clay, there is no appearance of trunks, or other vegetable impressions, beyond slender leaves, as of a long grass."

" The fact, that particular strata accompany the main coal for many square miles, would support the idea, that an immense flat was originally covered with the substance of this fire-clay, many feet thick, and that, upon this flat, there took place an uniform growth of a distinct single vegetation, which must have occupied the position for a long period, and thus furnished the substance which composes the *main coal.* The alternations of fire-clay and coal-seams would favor the notion, that these materials were originally mixed together in a fluid, and that those of the former, by their gravity, would first subside, whilst the vegetable matter, or those of the latter, would undergo a more gradual deposition. Hence, by a repetition of the process, the alternations of the strata would be produced. Besides, it may be supposed, that if the strata of coal have derived their origin from the growth and destruction of a forest, some portions of them would have been thicker than others, and altered in quality, or have retained, at least, some traces of forest trees; whereas, on the contrary, most extraordinary uniformity in quality, compactness, and thickness of the seams, prevails to a great extent." *

* Geological Facts, by Edward Mammatt, p. 73.

of one uniform material, almost invariably present, composed of finely divided particles, the beds overlying the coal consist of nearly every variety of rock embraced in the formation, though they are more usually some form of laminated carbonaceous slate. Both in composition and structure, the roof rock manifests signs of having been deposited by a more or less rapid current. In place of a single species of fossil plant, it usually includes a prodigious variety, and the delicate ramifications of these, instead of intersecting the bed in various directions, as the processes of the Stigmaria do in the fire-clay, lie in a singularly disordered and fragmentary condition, in planes almost invariably parallel to the bedding. Lindley and Hutton, in their work on the Fossil Flora of Great Britain, give the following very accurate description of the mode in which the organic remains occur in the roof slates in England, and the account is equally applicable to those of the United States: — "It is the beds of shale or argillaceous schistus, which afford the most abundant supply of these curious relics of a former world; the fine particles of which they are composed having sealed up and retained in wonderful perfection and beauty the most delicate forms of the vegetable organic structure. Where shale forms the roof of the workable seams of coal, as it generally does, we have the most abundant display of fossils. The principal deposit is not in immediate contact with the coal, but from twelve to twenty inches above it, and such is the immense profusion in this situation, that they are not unfrequently the cause of very serious accidents, by breaking the adhesion of the shale-bed, and causing it to separate and fall, when, by the operation of the miner, the coal, which supported it, is removed. After an extensive fall of this kind has taken place, it is a curious sight to see the mine, covered with these vegetable forms, some of them of great beauty and delicacy; *and the observer cannot fail to be struck with the extraordinary confusion, and the numerous marks of strong mechanical action, exhibited by their broken and disjointed remains.*" Such is the nature of the roof, when it consists of the usual carbonaceous shale or slate, but it is oftentimes a much coarser rock in the Appalachian coal-fields; being either an argillaceous flaggy sandstone, or a coarse arenaceous grit, or even, occasionally, a siliceous conglomerate. In these instances, the inclosed vegetable remains are for the most part fragments of the larger stems or branches of gigantic arborescent plants, their fronds and leaves being less abundant. These fragments occur in all postures, as respects the plane of the bedding, horizontally, obliquely, or perpendicularly; and betray, in their broken condition and irregular mode of dispersion, the sudden and tempestuous character of the currents which drifted and entombed them. Though the arenaceous rocks, having these features, sometimes rest in immediate contact with the upper surface of the beds of coal, they more frequently lie at a moderate distance over them, an argillaceous, laminated slate interposing to form the actual roof. A further indication of the violence of the currents, which strewed these coarse materials over the coal, is sometimes to be detected in the composition of the lowest portion of the overlying bed of grit or sandstone, in which a large amount of coal, in the state of powder or sand, is disseminated in the rock, giving it a dark, speckled appearance. This is of very common occurrence in the anthracite coal strata of Pennsylvania, where the coarse grit not unfrequently rests immediately on the coal. It implies, I conceive, the erosion of a certain portion of the upper surface of the soft, carbonaceous mass by the friction of the sandy current. The coaly matter, thus disturbed, would subside with the first layers of the sand, with which it was mingled. Mr. Logan has mentioned a still more striking proof of the energy of the movements which occasionally occurred, during the formation of the coal-measures. He gives an account of actual boulders, or rounded pebbles of coal, in the Pennant grit, and other coarse strata of the coal-field of South Wales.

Of the direct contact of Coal-Beds and Marine Limestones.

In the preceding account of the strata immediately below and above the seams of coal, I intentionally omitted to introduce the limestones, which occasionally compose the floor or the roof, sometimes in direct contact with the coal. The portion of the

Appalachian coal-formation, in which this remarkable contiguity of marine calcareous strata and vegetable or terrestrial coal occurs, is the great western basin of the Allegheny and Ohio rivers. I have already mentioned the abundance of unquestionably oceanic limestones in this coal-field, and given my inferences from the interesting fact, that they augment in thickness, and multiply in number, in crossing the region northwestward. As, however, the actual contact of beds of coal and limestone is of rare occurrence in the coal-fields of other countries, and as the circumstance must have an influential bearing on all our speculations concerning the physical conditions prevailing at the formation of the strata, and, to a certain extent, on our whole theory of the origin of coal, I shall here describe some of the best known instances before I reason concerning them.

Confining our attention to the great western basin, where the most striking cases occur, the following instances of this contact present themselves, in the ascending order.

1st. In the lower division of the main coal-measures, there occurs, near the town of Mercer, in Pennsylvania, a seam of good coal, having a thickness of about two feet, which is immediately overlaid by a bed of very pure limestone, also about two feet thick, containing a variety of marine organic remains of the genera *Terebratula*, *Bellerophon*, &c. In some spots, the pure coal is not separated from the pure limestone by more than a single inch, or at most two inches, and then the interval is filled with a calcareo-carbonaceous shale.

2nd. Higher in the series, but still in the lower part of the main coal-measures of western Pennsylvania, we meet with a bed of fossiliferous limestone, the thickness of which, in many neighborhoods, near the Allegheny river, is about fifteen feet. It contains several oceanic species, among them some *Crinoideæ*, two species of *Terebratula*, and a *Goniatites*. In some places, this stratum embraces a thin seam of coal, four inches thick, in almost direct contact with the limestone.

3d. The limestone, which is the first underneath the Pittsburg seam, contains a bed of coal one foot in thickness, separating two of its lower layers.

4th. Near Pittsburg, the great coal-seam frequently rests within a few inches of this underlying limestone, in which are a few occasional fossils, all of marine genera. In these places the dividing layer is only a few inches thick, and consists of a bluish fire-clay.

5th. In Fayette county, Pennsylvania, the great limestone, which lies above the Pittsburg coal-bed, incloses very generally two thin seams of perfect coal, immediately in contact with the layers of the rock. These coals appear to have considerable range, extending into the adjoining counties. The largest is occasionally two and a half feet thick, and a few inches of black calcareous slate alone separate it from the hard limestone. The other coal-bed has a thickness of about one foot, and its surfaces are in equally close contact with the limestone. Neither of these beds is as widely expanded as the including limestone.

6th. Underneath the uppermost workable bed of coal in western Pennsylvania, or that which I have termed in my Reports the Waynesburg seam, there is a stratum of limestone, which sometimes incloses a thin coal-bed, measuring about one foot.

7th. At Putnam Hill, near Zanesville, in Ohio, a bed of limestone, five feet thick, rests, according to Dr. Hildreth, on a seam of coal of one foot, there not being more than two inches of fire-clay interposed. The limestone contains *Encrini*, *Terebratulæ*, and other marine fossils.*

8th. The same writer mentions, that on the Clear Fork of Little Muskingum, in Ohio, there is a seam of good bituminous coal, three feet thick, reposing directly on a dark carbonaceous fossiliferous limestone, eight feet in thickness. It is overlaid by another limestone, measuring six feet, from which it is separated by a very thin layer of shale.

9th. Dr. Hildreth further states, that on Wills's creek, in the same region, a coal-seam, five feet thick, occurs, resting immediately on a bed of limestone, the thickness of which is twenty feet.

I might cite a large additional number of cases in Pennsylva-

* Hildreth, in American Journal of Science, p. 31.

nia, Virginia, and Ohio, in proof of the frequency of the contact of the coal-seams and beds of limestone; but I have been disposed to establish the fact, chiefly, from instances in different portions of the formation, and to show, that the contiguity of the coal and limestone is often maintained throughout a considerable extent of country.

Theory of the Origin of the Coal Strata.

Having presented what, I trust, is a sufficiently full sketch of the leading phenomena of the Appalachian coal-measures, and shown their correspondence, in several essential features of structure, to the coal-formation of Europe, I shall proceed now to consider what inferences we are entitled to draw respecting their origin, and that of the coal-formation generally. But, before taking this theoretical survey, it will be expedient to state, succinctly, the views of the several eminent geologists, who have recently written on this subject. I feel it the more incumbent to do this, since some of the speculations I shall advance are but modifications of hypotheses already published.

From a passage in Mr. Lyell's admirable work on the Elements of Geology, it appears, that M. Adolphe Brongniart, after comparing the phenomena of the ancient coal, and its fossil plants, with the great peat-mosses of the present day, states, in a memoir published in 1838, that he continues to adhere to the opinions originally advanced by Werner and De Luc, that the vegetation entombed in the carboniferous strata, chiefly grew in the localities where the coal is now found.* Whether Mr. Brongniart, however, endeavors to conform this view to all the phenomena of the coal-measures, under any general theory of their origin, I am not informed, not having seen his memoir.

Mr. Hawkshaw, in a communication to the Geological Society of London, in 1839, describes the remarkable phenomenon of five fossil trees, exposed in a cutting on the Manchester and Bolton railway, standing erect in relation to a bed of coal, eight or ten

* Lyell's Elements, Vol. II, p. 135, Boston edition.

inches thick, and in the same place with their roots. The largest of these was five feet in diameter, at the base, and eleven feet high. He conceives it probable, that they grew where they occur.* In a subsequent paper, read February 26, 1840, Mr. Hawkshaw, after mentioning the discovery of another fossil tree, standing on the same coal-seam, makes this observation : "If the coal be considered as the debris of a forest, it is difficult to account for not finding more trunks of trees than have been discovered in our coal-basins, and it is only, perhaps, by allowing the original of our coal-seams to have been a combination of vegetable matter, analogous to peat, that the difficulty can be solved."†

After Mr. Hawkshaw's first communication, Mr. Beaumont, in a paper read to the same Society, November 6th, 1839, upon the subject of the same trees, states several objections to the drift theory of coal, and conceives, that the vegetation grew where it is found. Upon comparing these objections with my own, as given in the foregoing pages, I find that they all rest upon a different class of facts, and are wholly distinct in their bearings. Mr. Beaumont states, that the vegetation which formed the coal grew on swampy islands, that it consisted of *ferns*, *calamites*, *coniferous trees*, &c., which operated, through their decay and regeneration, to form peat bogs; and that the islands, by subsiding, were covered with drifted sand, clay, and shells, till they again became dry land, and supported another vegetation; and this process, he supposes, was repeated as often as there are coal-seams.‡

Dr. Buckland, in commenting on this hypothesis, observes, that, "in denying altogether the presence of drifted plants, the opinion of the author seems erroneous; universal negative propositions are in all cases dangerous, and more especially so in geology. That some of the trees, which are found erect in the coal-formation, have not been drifted, is, I think, established on sufficient evidence; but there is equal evidence to show, that other trees and leaves innumerable, which pervade the strata that

* HAWKSHAW, in Proceedings Geological Society, London, No. 64.

† HAWKSHAW, in Proceedings Geological Society, London, No. 69.

‡ BEAUMONT, in Proceedings of Geological Society, London, No 65.

alternate with the coal, have been removed by water to considerable distances, from the spots on which they grew. Proofs are daily increasing in favor of both opinions, namely, that some of the vegetables which form our beds of coal grew on the identical banks of sand, and silt, and mud, which, being now indurated to stone and shale, form the strata that accompany the coal; whilst other portions of these plants have been drifted to various distances from the swamps, savannahs, and forests, that gave them birth; particularly those, that are dispersed through the sandstones, or mixed with fishes in the shale beds.* In these views of Dr. Buckland, Mr. Lyell would seem to concur, as, in quoting the above passage, in his Elements, he says, that "it can be no longer doubted, that both these opinions are true, if we confine our attention to particular places."

Another paper, on the same subject of the fossil trees, found on the Manchester and Bolton railway, was read contemporaneously with the last communication of Mr. Hawkshaw. The author, Mr. Bowman, is of opinion, "that the theory of the subsidence of the land during the carboniferous era, receives much support from the phenomena presented by these fossil trees." He does not deny, that plants may have been carried into the water from neighboring lands; but he conceives it difficult to understand whence the vast masses of vegetables, necessary to form thick seams of coal, could have been derived, if drifted, and how they could have been sunk to the bottom without being intermixed with the earthy sediment, which was slowly deposited upon them. Another difficulty of the drift theory, he says, "is the uniformity of the distribution of the vegetable matter throughout such great areas as those occupied by the seams of coal." I have myself shown, that this uniformity extends even to the subordinate divisions of each seam. Mr. Bowman believes, that the coal has been formed from plants, which grew on the areas now occupied by the seams; that each successive race of vegetation was gradually submerged beneath the level of the water, and covered up by sediment, which accumulated till it formed another

* Anniversary Address to Geological Society, 1841.

dry surface for the growth of another series of *trees* and plants, and that the submergences and accumulations took place as many times as there are seams of coal.*

In reviewing the above facts and opinions, Dr. Buckland conceives, that a luxuriant growth of marsh plants, as *Calamites*, *Lepidodendra*, *Sigillaria*, &c., may have formed a superstratum of coal, resting on a substratum of the same, composed exclusively of remains of *Stigmariæ;* and in accounting for the marine and freshwater strata alternating with the coal-beds, he appeals to the intermitting and alternate processes of subsidence, drift, and vegetable growth.†

The above summary of the recent researches and speculations of geologists, conveys, I believe, a correct view of the state of opinion at the present time, in relation to the interesting problem of the origin of the coal strata. I may now venture to advance my own explanation of the phenomena, and to indicate wherein I differ from the able authors I have cited. The several hypotheses proposed, do not attempt to account for some of the most remarkable relationships among the strata, such as the extraordinary frequency, beneath the coal-beds, of the Stigmaria clay, the very general occurrence of laminated slates immediately above the seams, and the singular contrast which these underlying and overlying rocks present, in the variety and condition of the imbedded vegetable remains. Nor do they explain satisfactorily why the coal itself contains so few traces of the forest trees of the period, either in a prostrate or erect position; while their broken stems are mingled with the fragmentary parts of the Stigmaria, in more or less abundance, in all the coarser rocks. Perhaps the following hypothesis will account for the phenomena.

Let us imagine the areas now covered with the coal-formation, to have possessed a physical geography, in which the principal feature was the existence of extensive flats, bordering a continent, and forming the shores of an ocean, or some vast bay, outside of which was a wide expanse of shallow but open sea. Let us now

* Bowman in Proceedings Geological Society, London, No. 69.

† Anniversary Address to Geological Society, 1841.

suppose, that the whole period of the coal-measures was characterized by a *general* slow subsidence of these coasts, on which we conceive that the vegetation of the coal grew; — that this vertical depression, was, however, interrupted by pauses and gradual upward movements of less frequency and duration, and that these nearly statical conditions of the land, alternated with great paroxysmal displacements of the level, caused by those mighty pulsations of the crust which we call earthquakes. Let us further conceive, that during the periods of gentle depression, or almost absolute rest, the low coast was fringed by great marshy tracts or peat-bogs, derived from and supporting a luxuriant growth of *Stigmariæ*, and that along the land-ward margin, and in the drier places of these extensive sea morasses, grew the *Coniferæ*, *Tree-Ferns*, *Lycopodiæceæ*, and other arborescent plants, whose remains are so profusely scattered throughout the coarser strata between the coal-seams. In this condition of things, the constant decomposition and growth of the meadows of *Stigmariæ*, would produce a very uniform, extended stratum of pulpy but minutely laminated pure peat. This would receive occasional contributions from the sheddings by the dispersed trees of their leaves, fronds, and smaller portions, which, being driven by winds, or floated on the high tides, would lodge among the Stigmariæ in the marshes, and slightly augment the deposit. These leaves and fronds, covered over more or less rapidly by the growing *Stigmariæ*, or varying in their tendency to decay, according to the abundance or deficiency of their juices, would, when thus inclosed, pass at once either to the pulpy state, and ultimately form coal, or, by the more rapid extrication of their volatile portions, remain as mineral charcoal, and preserve their vegetable fibrous structure. In both of these conditions of coal and charcoal, we often find the smaller parts of plants retaining their organized forms among the laminæ of the purest coal-seams. Upon this view of a gradual accumulation from the *Stigmariæ*, assisted by the deciduous parts of the trees, it is altogether unnecessary to suppose, that any portions, even the upper layers of the coal-beds, derived their vegetable matter from the stems of the trees themselves. Thus the absence of trunks and roots from the coal is reconciled with the occasional occurrence of their fronds and lighter extremities. Upon no other hypothesis respecting the physical condition of the region which produced the coal vegetation than that here imagined, can I explain the singular infrequency of fossil trunks standing on or in the coal, or account for their occasional occurrence, as in the instances described by Hawkshaw and Bowman. No other supposition seems to furnish a cause for the absence of all traces in the coal itself, of the larger parts of arborescent plants, and for their equally remarkable abundance in a broken and dispersed state in the overlying strata.

Assuming such to have been the condition of the surface during the tranquil periods of the accumulation of each coal-bed, we may conceive the other strata to have been produced in the following manner. Let us suppose an earthquake, possessing the characteristic undulatory movement of the crust, in which I believe all earthquakes essentially to consist, suddenly to have disturbed the level of the wide peat-morasses and adjoining flat tracts of forest on the one side, and shallow sea on the other. The ocean, as usual in earthquakes, would drain off its waters for a moment from the great Stigmaria marsh, and from all the swampy forests which skirted it, and, by its recession, stir up the muddy soil, and drift away the fronds, twigs, and smaller plants, and spread these, and the mud, broadly over the surface of the bog. In this way may have been formed the laminated slates, so full of fragmentary leaves and twigs, which generally compose the immediate covering of the coal-beds. Presently, however, the sea would roll in with impetuous force, and, reaching the fast land, prostrate every thing before it. Almost the entire forest would be uprooted and borne off on its tremendous surf. Spreading far inland, compared with its accustomed shore, it would wash up the soil and abrade whatever fragmentary materials lay in its path, and, loaded with these, it would then rush out again, with irresistible violence, towards its deeper bed, strewing the products of the land in a coarse promiscuous stratum, imbedding the fragments of the broken and disordered trees. Alternately swelling and retiring, with a suddenness and energy far surpassing that of any tide, and maintained probably in this state of tempestuous oscillation, by fresh heavings of the crust, the waters would go on spreading a succession of coarser or finer strata, and entombing at each inundation a new portion of the floating forest. Upon the dying away of the earthquake undulations, the sea, once more restored to tranquillity, would hold in suspension at last, only the most finely subdivided sedimentary matter, and the most buoyant of the uptorn vegetation, that is to say, the argillaceous particles of the fire-clay, and the naturally floating hollow stems of the *Stigmariæ.* These would at last precipitate themselves together, by a slow subsidence, and form a uniform deposit, exhibiting but few traces of any active horizontal currents, such as would arise from a drifting into the sea from rivers. The chief portion of the coarser fire-clay would settle first, and then the more impalpable particles, in company with the stems and leaves of the *Stigmariæ.* Thus we may account for the constant reproduction of the peculiar soil of the coal-seams, and for the preservation, particularly in its upper layers, of the Stigmaria plant; the simple consequence of the final subsidence of these materials, being the production of the necessary substratum of another coal-marsh. The marine savannahs becoming again clothed with their spongy matting of *Stigmariæ*, and fringed on the side towards the land with wet fórests of arborescent Ferns, all the essential conditions and changes that constituted this wonderful cycle in the statical and dynamic processes belonging to each seam of coal, and the beds enclosing it, would be completed, and ready to be once more renewed. In the hypothesis now proposed, the great relative buoyancy of the *Stigmariæ* is considered, and we have the testimony of Dr. Buckland and others, to show that it was a plant admirably fitted by its structure, to float upon the surface of the water.

Though the train of actions here imagined enables us to reconcile the indications afforded by the coal-beds, of periods of prolonged tranquillity, with the evidences of violent aqueous currents, as shown in the composition of the coarser mechanical rocks; yet a complete theory of the coal-formation calls for the introduction of other considerations connected with the existence and positions of strata, derived from chemical and organic agencies, as the limestones, cherts, and beds of carbonate of iron. The analysis already given of our Appalachian coal-measures, will be seen to imply a slow general subsidence, alternating with occasional and less prolonged movements of elevation; these gentle changes of level, interrupted by sudden or paroxysmal heavings of the crust. Mr. Beaumont was the first, I believe, to suggest a subsidence of the land during the progress of the coal-formation; he supposes the coal-beds to be the result of a "luxuriant vegetation, covering swampy islands, which, by the settling down of the disturbed crust of the earth, were covered over with drifted sand, clay, &c." Subsequently Mr. Lyell, in the last edition of his Elements of Geology, proposes a somewhat similar view. He says, "If the superposition on a great scale of purely marine strata to others containing coal and fresh-water shells, leads us to infer that large areas, once constituting estuaries, deltas, and marshes, sank down and became sea during the carboniferous period, so are there reasons for concluding, that in many cases the depression of the ground took place gradually, and that in consequence of the deposition of sediment, the same space was again and again converted into land and laid under water." In another passage he suggests, that "If we appreciate the full strength of the evidence in favor of continued subsidence in the coal-field of South Wales, we shall be the less surprised to learn that the vertical depth of the superimposed strata is enormous, amounting in some places to no less than twelve thousand feet."* Though a vast preponderance of subsidence over elevation is plainly indicated in the prodigious thickness of the coal-measures, each particular coal-seam in which was produced successively at the surface, I cannot conceive that either an alternation of periods of subsidence and repose, or an uninterrupted prolonged depression, will explain the phenomena of the Appalachian coal rocks, as they have been here described. A general subsidence throughout the coal period, of all the great area now occupied by the Appalachian basins, is proved independently of the above evidence derived from the nature of the coal-beds, by the interesting fact, that the lower seams of Ohio and western Pennsylvania, have

* Lyell's Elements, Bost. edit., Vol. II., pp. 128 and 134.

their eastern limit more than one hundred and fifty miles to the west of the general eastern boundary of the upper ones; and, as we ascend in the formation, the beds extend successively more and more to the east, or in the direction of the ancient land. But considering the many striking instances which I have recorded, of the close approach or actual contact of certain beds of coal and oceanic limestone, we cannot resist the conclusion, that the gradual downward movement was frequently interrupted by a slow upward one. In all the instances that I have cited, where the limestone stratum immediately underlies a coal-seam, it is obvious that an upward movement of the land must have taken place, so gradually as to be unattended by any sensible commotion of the waters. A considerable and sudden lifting of the bed of the sea, would infallibly have caused the production of violent currents, competent to spread over the quiet precipitate of limestone, one or more coarse arenaceous or argillo-arenaceous strata. That the intervals of repose, indicated by the limestones, were, like those of the beds of coal, sometimes suddenly terminated by earthquake disturbances, strêwing over the marine sediments the materials of the land, is manifest from the phenomena, though it is not less clear, that the cessation of the periods of relative tranquillity, marked by very gradual subsidence, must, in all cases, where the coal-beds are overlaid directly by marine limestones, have been effected by simply a more rapid process of depression. Every superimposed limestone, without an intervening roof-slate, or sandstone, to separate it from the coal, affords, I conceive, a conclusive proof of this increased rate of submergence. Perhaps it will be objected, that a merely accelerated subsidence, such as I have here supposed, if taken in conjunction with the hypothesis of a drifting of the land materials by rivers, will satisfactorily explain all the facts which I have ascribed to the turbulent movement of the sea against the land during earthquakes. But though it is highly probable, from the phenomena of nearly every extensive coal-field, that rivers did carry into the parts of the ocean and its estuaries, now drained and occupied by the coal strata, a considerable quantity of argillaceous deltal deposits, yet it is difficult to imagine how any moderately rapid subsidence, if unaccompanied by some *paroxysmal* movement, could create a current energetic enough to uproot and float away nearly the whole of those vast forests, which evidently grew close to the site of each seam of coal, and to snap off to the stumps, even the most colossal trees. Nor is it easy to explain, why such a quiet submersion of the swampy forests did not result in the preservation of the trees in their original erect posture, by the drifting around them of the supposed river sediments. It is fair to infer, that so long a line of coast as we conceive bordered the Appalachian ocean, if we may judge from the great longitudinal extent of some of our coal-seams, was not destitute of rivers, and we are therefore constrained to admit that some amount of sedimentary matter must have entered the sea in that manner; but at the same time, we have only to notice the striking deficiency of earthy matter in the numerous coal-beds, and in many of the strata of limestone, to be persuaded, that the amount of material contributed to the coal-measures by fluviatile transport, was relatively inconsiderable. It may be fairly questioned, whether any sensible proportion of river silt, could spread itself to the distance of one hundred and fifty or two hundred miles seawards, over the great coal morasses of such a coast, and yet we must suppose this, if we deny the above paroxysmal theory.

That the geological and geographical changes known to have been caused in modern times by earthquakes, entitle us to speculate upon their agency in suddenly shifting the level of the low tracts once occupied by the marshes and swamps of the coal-seams, must, I think, be conceded. Few geologists will deny the probability of frequent changes, in the carboniferous period, analogous to that which took place in the great plain at the mouth of the Indus, in the year 1819. It is mentioned in Mr. Lyell's Elements, that "extensive flats bordering the Indus, sank down, and for many years after, vessels were forced through the boughs of the tamarisk trees, still standing erect."*

Should the foregoing theory, based on the complicated statical and dynamic phenomena of the Appalachian coal strata, be cor-

* Lyell's Elements, Vol. II, p. 136.

rect, then have we, in every stratum of the series, not merely a new picture of the physical geography of the region, but a clear legible record of the very changes, gradual or tempestuous, of which each in its turn was the result. We unclasp, as it were, a whole volume of hydrographic charts, displaying, for a vast succession of epochs, the ever-changing relations of the land and waters. A wide tract of ancient coast is at one time occupied by the ocean, at another by an immense plain, filled with green marshes and swamps, and at another by dry land, clothed with an impenetrable forest. But we behold more than merely these several conditions of the surface; we perceive the very transitions themselves which revolutionized the geography; we discern the ocean in the very act of encroaching on the land, forming extensive marshes, where before the whole was solid shore; we actually trace it in its gradual retreat, exposing its own marine sediments to form a fertile soil for vast savannahs of the *Stigmariæ*, and again we see the entire region embracing the dry land, the marshes, and the sea, heaving and undulating in the billows of the irresistible earthquake, the ocean and the land contending for mastery in the tremendous conflict.

If the Appalachian coal strata, whose history I have here endeavoured to interpret, exhibit truly the above-imagined conditions and events, we may consider the entire formation as constituting a stupendous tide-gage, registering the lengthened ebbings and flowings of that ancient sea, and the stormy agitations of its eternally oscillating waters, as the epoch of its last, greatest movement, and final drainage, drew near.

Of the Gradation in the Proportion of Volatile Matter in the Coal of the Appalachian Basins.

There prevails a very interesting law of gradation, in the quantity of volatile matter belonging to the coal, as we cross the Appalachian basins from the southeast towards the northwest. The extraordinary extent of area over which this law obtains, and its intimate connection with corresponding gradations in the structural phenomena of the region, the description and theory of which have been given by my brother and myself in another communication, seem to claim for it a place in the present general account of our coal-measures. The gradation may be thus briefly described. Crossing the Appalachian coal-fields, northwestward from the great valley, to the middle of the main or western trough, by any section between the northeastern termination of the formation in Pennsylvania, and the latitude of Tennessee, we find, as the result of multiplied chemical analyses, a progressive increase in the proportion of the volatile matter, passing from a nearly total deficiency of it, in the dryest anthracites, to an ample abundance in the richest caking coals. The existence of this singular law of transition was first ascertained by me in 1837, in which year I made mention of it in some public lectures. It was communicated to the Association of American Geologists, at their first Annual Meeting, in the spring of 1840; but I did not publish it in print until the following winter, when it was briefly alluded to in my fifth Annual Report on Pennsylvania. Evidence of the existence of such a gradation in the coals of western Virginia, will be found in the Annual Reports of the Geological Survey of that State, for the years 1839 and 1840. These historical references are here introduced, because the determination of the general fact was the result of many laborious analyses of our coals, made by my brother and myself, and because attempts have been made by others, to establish a claim to the discovery. The lists of analyses contained in the Reports of the Surveys of Pennsylvania and Virginia, and similar data not yet published, show the following as the general proportion of the bituminous matter, in the different belts of the formation, as we cross the region from southeast to northwest.

First. In the most southeasterly chain of basins, the coal is, for the most part, a genuine anthracite, containing sometimes, however, a small per centage of bitumen, and always a little gaseous matter, chiefly hydrogen. The quantity of the volatile matter varies according to geological locality, from about six to twelve or fourteen per cent. This first belt of basins embraces all the anthracite coal-fields of Pennsylvania, the slightly bituminous ones of Broad Top on the Juniata, of Sleepy creek, of the Little North mountain, of Catawba creek, Tom's creek, Strouble's run, and Brushy ridge, in Virginia. The coal of the Little North mountain, is, however, a true anthracite. All of these coal-fields, and insulated patches of the formation, belong to the most disturbed portions of the Appalachian chain, and they are associated with some of the boldest flexures and greatest dislocations of the whole region. The first or southeastern anthracite basin of Pennsylvania, presents innumerable sharp flexures and close plications, with inversion, of the strata.

Secondly. In the next well-defined range of basins further towards the northwest, that namely of the Allegheny mountain, and the general escarpment of which it is a part, the proportion of volatile matter varies usually from sixteen to twenty-two per cent.; but is generally about eighteen or twenty per cent. This belt includes all the coal-fields, situated immediately to the northwest of the Allegheny mountain, in Pennsylvania; also, the Potomac basin, in nearly the same line, and the coal-fields of the Little Sewell, and the eastern side of the Big Sewell mountain, in Virginia. The position of this belt of the coal-measures is somewhat west of the region of steep flexures of the strata, and beyond all the considerable dislocations; while it embraces a few very extensive, regular, and nearly symmetrical anticlinal axes of the flatter form, distinctive of their intermediate position between the east and west.

Thirdly. The great Appalachian basin, with its subordinate troughs, forming the wide coal-field watered by the Ohio river and its tributaries, embraces a series of coal-beds, which are all distinguished by a still larger amount of volatile matter. In crossing the breadth of this wide coal-field, we find a very material alteration in the character and composition of the coal. Along its eastern side, or near the last considerable axis of the Appalachian chain, the amount of volatile matter is commonly from thirty to thirty-five per cent. Westward of this line, on the Monongahela river, both in Pennsylvania and Virginia, the proportion approaches to forty per cent., while still further in the same direction, or near the Ohio river, it ranges from forty to even fifty per cent., according to local circumstances. In this most western or main coal-field, the flexures of the strata are extremely gentle, and comparatively wide apart; but, even here, we observe a beautiful progression in the amount of the bitumen, as we recede from the very low axes which traverse the southeastern side of the great plain. What renders the foregoing comparison of the several ranges of the coal-formation particularly exact and satisfactory is, the circumstance, that, in more than one instance, we are enabled to trace the very same coal-seam, through its various degrees of bituminization, from an almost true anthracite, to a form in which it possesses a full proportion of volatile matter. Thus the great Pittsburg bed, to take it as an example, contains on the Potomac, in some localities, as little as 15.5 per cent., but near the eastern margin of the great western basin, as at Blairsville, and again in Virginia, it has about thirty-one per cent, and towards the middle of the main basin at Pittsburg and on the Kenawha, as much as from forty to forty-three per cent.

The cause of the different degrees of de-bituminization of the coals, in different parts of their range, I am disposed to attribute to the prodigious quantity of intensely heated steam and gaseous matter, emitted through the crust of the earth, by the almost infinite number of cracks and crevices, which must have been produced during the undulation and permanent bending of the strata. All the phenomena of modern earthquakes and volcanos, warrant us in supposing that the elevation of our coal rocks, if effected in the manner I have imagined, must have been accompanied by the escape of an immense amount of hot vapors, the chemical and thermal agency of which cannot be overlooked, upon any hypothesis of the rending and uplifting of great mountain tracts. It is easy to conceive, that the coal, throughout all the eastern basins, if thus effectually steamed, and raised in temperature in every part of its mass, would discharge a greater or less proportion of its bitumen and other volatile constituents, as the strata were more or less frequently and violently undulated by earthquake action. It is also obvious, that the more western beds, remoter from the region of active movements, less crushed and fissured, and presenting a greater resistance to permeation by the subterranean vapors, would, in virtue of their mere geographical position in the chain, be much less extensively de-bituminized. The striking fact that we nowhere, not even in the most dislocated and disturbed districts of the anthracite coal-field, find any traces of true igneous rocks, that, by their contiguity to the coal, could have caused the loss of its bitumen, is a circumstance in their geology, which goes far to confirm the truth of the hypothesis. Precisely in proportion as the flexures of the strata diminish in our progress westward, does the quantity of the bitumen in the coal augment; but it is difficult to conceive how any such law of gradation could have been the result of a temperature transmitted by conduction from the general lava mass beneath the crust, for that would imply a corresponding increasing gradation in the thickness of the crust, advancing westward under the coal-fields, whereas such an inference is in direct conflict with the fact of the general diminution westward of the Appalachian rocks, besides being inconsistent with all correct geothermal considerations, which forbid our imagining so unequal a conduction to the surface, of the earth's interior temperature.

On the Physical Structure of the Appalachian Chain, as exemplifying the Laws which have regulated the Elevation of great Mountain Chains, generally.

By W. B. Rogers, *Professor of Natural Philosophy in the University of Virginia, and* H. D. Rogers, *Professor of Geology in the University of Pennsylvania.*

Having, in the prosecution of the State Geological Surveys of New Jersey, Pennsylvania, and Virginia, arrived at certain general facts in the structure of the Appalachian chain, involving some new considerations in Geological Dynamics, we propose, in the present memoir, to offer a description and theory of the phenomena. As similar structural features would appear, upon comparison, to prevail in many of the disturbed regions of other countries, and among strata of all geological dates, an exposition of their laws cannot be uninteresting at this time, when every question connected with the elevation of the earth's crust, is receiving so generally the attention of geologists.

To render our details intelligible in the absence of a geological map, we must first enter upon a brief geographical description of the extensive zone of country where these structural conditions exist. Such a preliminary sketch is the more essential, since, in no region yet described, does the topography or physical relief of the surface, afford as accurate an index to the positions and relations of the strata, and to the movements by which they have been uplifted.

The Appalachian chain rises in the form of a broad belt of mountain ridges east of the St. Lawrence, in the northern part of New England, and, taking a southwesterly course, terminates in Alabama. Its total length is about one thousand three hundred miles, and its greatest breadth about one hundred, if we exclude from this description the high insulated tracts of the White Mountains in New Hampshire, and that west of Lake Champlain, in New York. From the northern border of Vermont, the main chain gradually expands in width to the region of the Juniata and Potomac rivers, beyond which, in its progress to the southwest, it slowly and steadily contracts to its termination. While the great chains of many countries contain a principal central mountain axis, to which all the minor ranges more or less conform, this system consists of a broad zone of almost innumerable parallel ridges of nearly equal average height. These seldom reach an elevation of four thousand feet above the sea; nor, if we except the great eastern range, the Blue ridge, do they often rise more than two thousand feet from the level of the adjoining valleys, the more usual height being from eight hundred to one thousand five hundred feet. The general plain, supporting this broad mountain belt, gradually declines in level from the head waters of the Holston and Clinch rivers, in Virginia, towards both extremities.

The characteristic features of the Appalachian ridges, are their great length, narrowness, and steepness; the evenness of their summits, and their remarkable parallelism. Many of them are almost perfectly straight for a distance of more than fifty miles; and this feature, combined with their steep slopes, and sharp, level summits, gives them the appearance, seen in perspective, of so many colossal entrenchments. Some groups of them are curved, but the outlines of all are marked by soft transitions, and an astonishing degree of regularity. It is rather the number and great length of the ridges, and the magnitude of the belt which they constitute, than their individual grandeur or height, that places this chain among the great mountain systems of the globe. From the latitude of the Mohawk river, in New York, to the northern boundary of Alabama, the chain in general consists of four parallel belts, the separate features of which it is convenient we should define.

1. The first or southeastern subdivision is the relatively narrow, undulating mountain range, which, in Vermont, is called the Green Mountains, in New York the Highlands, in Pennsylvania the South Mountain, in Virginia the Blue Ridge, and in North Carolina and Tennessee the Smoky or Unaka mountains. This is rather a zone of closely united ridges, than one great mountain axis, though the latter is somewhat its character in Virginia, North Carolina, and Tennessee, in which States it has its greatest breadth and elevation. The average width of this belt may be stated at about fifteen miles, and its height, which is more variable than that of any other portion of the general chain, undulates between about one thousand and five thousand feet above the sea.

The rocks of this tract consist for the most part of the older metamorphic strata, including gneiss, and micaceous, chloritic, talcose, and argillaceous schists, together with masses referable to the earliest Appalachian formations, sometimes in a highly altered condition. Throughout nearly the whole distance, from Tennessee to the Susquehanna, these latter rocks occupy the northwestern slope of the main ridge, and form the ranges of hills, sometimes of great height, flanking it on the northwest; while in Pennsylvania, New Jersey, Massachusetts, and Vermont, besides presenting themselves in this position, they form narrow belts and ridges among the older metamorphic strata towards the southeast.

Innumerable dykes and veins of all dimensions, and consisting of a vast variety of igneous materials, penetrate this belt, disturbing and altering its strata in a remarkable degree.

2. Immediately to the northwest of this mountain range is a broad valley, which constitutes by itself a well-defined belt throughout the entire length of the chain, displaying a remarkable constancy in its structure and physical features. This, which we shall call the *Great Appalachian Valley*, ranges from Vermont to Alabama, under various local names, being known in New York as the Valley of Lake Champlain and the Hudson river, in Pennsylvania as the Kittatinny or Cumberland Valley, and further south successively, as the Great Valley of Virginia and the Valley of East Tennessee. Its average breadth throughout, is about fifteen miles, forming an unbroken and nearly level plain, except in Virginia and eastern Tennessee, where several long insulated ridges, rising in it, separate it for a greater or less distance into two or more narrow parallel valleys. The stratification every where in this great belt is exceedingly disturbed, the rocks consisting principally of the three lower Appalachian formations, being, only in a very few instances, invaded, however, by igneous dykes.

3. Beyond the *Great Appalachian Valley* on the northwest, is a wide belt of long, narrow, parallel ridges and included valleys, spreading northwestward to the foot of the great plateau of the Allegheny and Cumberland mountains. This, which we propose to call the *Middle Mountain-belt*, has a breadth varying from thirty to sixty miles, its greatest expansion being in the curving region of the Juniata in Pennsylvania. It embraces all the Appalachian formations to the coal inclusive.

4. The fourth or most northwestern of the belts into which we have divided the Appalachian chain, commences with the southeastern escarpment of the great table-land of the Catskill, Allegheny, and Cumberland mountains, and spreads northwestward with a gentle declivity, as far as the limits of the last feeble axes of elevation. The average breadth of this belt, measured from the southeastern escarpment of the plateau, to the plain which

bounds it on the northwest, may be stated at about thirty-five miles. This portion of the chain embraces all the upper Appalachian formations, including the whole of the carboniferous group.

Following the course of this great mountain belt from Canada to Alabama, it will be seen to consist of a series of nine straight and curved portions in alternate succession, distinguished from one another by important topographical features, as well as by peculiarities of geological structure, *and forming nine distinct divisions.*

1. Of these the first, or *Hudson River Division*, extends from Canada to New Jersey, following the general course of the Hudson as far as the Highlands in New York, and comprising not only a large area in the eastern and northern parts of that State, but a considerable tract in western Vermont and Massachusetts. Along the great valley, from the northern part of Vermont to the passage of the Hudson through the Highlands, the strike of the rocks, and the direction of the axes, is about north fifteen degrees east, and south fifteen degrees west.

2. From where the Hudson crosses the Highlands, to the Lehigh river in Pennsylvania, the whole chain *bends* gradually westward, taking a long and regular sweep concave to the northwest. This portion of the chain we propose to call the *Delaware Division.*

3. The next is a nearly *straight* part of the chain; extending from the Lehigh river to Cumberland county, in Pennsylvania, and may very properly be named the *Susquehanna Division.* Throughout this tract the strike is from east-northeast to west-southwest.

4. To the southwest of the foregoing is the highly interesting *curving* portion of the chain, which we shall call the *Juniata Division.* This diversified region extends from about twenty miles west of the Susquehanna, to nearly the same distance north of the State line of Maryland, and is characterized by a regular and very decided curvature, convex towards the northwest. The formations, in ranging between the above limits, change their strike from south seventy degrees west, to south thirty degrees

west, undergoing thus a deviation in their course of forty degrees.

5. The next division is one of *straight* or nearly straight axes. It extends from the southern counties of Pennsylvania, to the southern side of Augusta, Pendleton, and Randolph counties, in Virginia, with a strike of the rocks about north thirty east, or south thirty west. This we shall call the *Potomac Division.*

6. The portion of the chain next succeeding, has a decided *sweep*, concave towards the northwest. It extends from the southern limit of the previous one to the New river, and, being extensively watered by the tributaries of the James river, may be designated as the *James River Division.* The belt here referred to differs from the three last, in possessing a less symmetrical topography, and a less regular strike in its strata. Its axes are also shorter and less perfectly parallel, and the whole tract is considerably narrower, the width, from the Blue ridge northwestward, across which the undulations of the strata extend, not exceeding sixty miles.

7. The division next in order, which is one of *straight* axes, commences northeast of the New river, in Virginia, and extends nearly to the mouth of the Holston, in Tennessee. Being watered for a great distance longitudinally, by the latter stream, it may be appropriately named the *Holston Division.* Both in the style of the topography, and the phenomena connected with the dipping of the strata, this is one of the most remarkable parts of the chain. The direction of its axes and faults is about north sixty-seven east, and south sixty-seven west. Its length exceeds two hundred miles, but its breadth is somewhat inferior to that of any of the previous divisions, not amounting to more than fifty-five miles from the Blue ridge to the most northwestern axis.

8. At the southern termination of the belt above described, near the mouth of the Holston, commences the next division of the chain. This has a *curving* outline, concave towards the northwest, the direction of the axes and the strike of all the strata, gradually changing from south sixty-seven west, to south thirty-five west, making a deflection of thirty-two degrees. Traversing the central parts of eastern Tennessee, and including in it the

well known town of Knoxville, it may be entitled the *Knoxville division.* In this, as in the division last mentioned, the whole disturbed space is comparatively narrow.

9. The last or ninth division of the chain extends from the southern termination of the Knoxville section, near the mouth of the Clinch river, to the neighborhood of Tuscaloosa, in the centre of Alabama. This we propose to call the *Alabama Division.* Unlike the district just preceding, it exhibits almost perfect *straightness* in its axes; the strike, which is about south thirty-five west, continuing unchanged until the strata disappear beneath the horizontal formations of the cretaceous and tertiary systems of middle Alabama.

Predominance of Southeastern Dips.

While the general direction of the Appalachian chain is northeast and southwest, there is a remarkable predominance of southeastern dips throughout its entire length from Canada to Alabama. This is particularly the case along the southeastern or most disturbed side of the belt, where it is strikingly exhibited in the great valley, and in the extensive mountain ridges that bound it on the southeast. But, as we proceed towards the northwest, or from the region of greatest disturbance, the opposite, or northwest dips, which previously were of rare occurrence, and always very steep, become progressively more numerous, and, as a general rule, more gentle.

Of the prevalence of this interesting general law throughout all the part of the chain extending from western Massachusetts into eastern Tennessee, we have convinced ourselves by a personal examination of the entire tract, during the last six years, and have partially announced it in various passages of our Reports on the Geology of New Jersey, Pennsylvania, and Virginia. We learn from Dr. Charles T. Jackson, and other sources, that the prevailing southeastern dip extends to western Vermont, and the valley of Lake Champlain.

Upon the correct interpretation of this singular feature depends, we conceive, the clear elucidation of whatever relates to the dynamical actions which the region has experienced, to the strata-graphical arrangement of the rocks, and, as immediately connected with this, to the distribution of their organic remains. The object of the present paper is, to exhibit those general laws of structure, of which the feature in question is but a simple and immediate consequence, and to develope what we have for several years past regarded as the true theory of the flexure and elevation of the Appalachian rocks.

History of the previous Explanations of the general southeasterly Dip in the Great Appalachian Valley.

The first published attempt at explaining the seeming anomaly of a general southeasterly dip across the great valley, was made by Prof. Hitchcock, in the first edition of his Report of the Geology of Massachusetts, in 1833. This explanation, which was confined to the phenomena of western Massachusetts, supposes a series of unconformable deposits all dipping to the east, at different angles; but Prof. Hitchcock does not suggest the idea of either an inversion or a folding of the rocks.

At an early period in the geological surveys of New Jersey, Pennsylvania, and Virginia, we were struck with the great prevalence of the southeasterly dip of the strata throughout the portions of the Appalachian chain traversing those States, and recognized its dependence on the oblique or inverted folding of the strata. This will appear from the descriptions we have given of the phenomena, in our Annual Reports for 1837 to 1839. The important general law of a greater steepness of the dip on the northwestern than the southeastern sides of the anticlinal axes, became known to us at the same stage of our inquiries, and was first announced in the Final Report on the Geology of New Jersey, written in 1839, and published early in the spring of 1840.

Our solution of this question of the southeasterly dips, which we have long supposed to constitute the only key to the structure of our great mountain chain, was communicated in conversation to Professors Hitchcock and Emmons, at the first Annual Meeting of the Association of American Geologists, in the spring of 1840.

The next notice in the order of time of this structure is, that given by Prof. Hitchcock in his Elementary Geology, published in August, 1840. In this work, Prof. H. refers to our published observations respecting the extensive inversion of the strata in Pennsylvania and Virginia, and proposes to explain the prevailing southeasterly dip in western Massachusetts, and the Hudson river district, by the hypothesis of a simple but vast inversion of all the rocks extending entirely across the region in question. This explanation, accompanied by a short section through the Hoosic and Taconic mountains, is given as an instance of *inversion*, and not of the *folding* of strata, the latter subject being discussed separately on another page.

At a meeting of the American Philosophical Society, on the first of January, 1841, one of us communicated the results of some observations upon the geological structure of Berkshire, Mass., and the neighboring parts of New York, which we had made during the month of August previous, and gave an outline orally of our theory, explanatory of the phenomena. After adverting to the statements of previous writers, that all the strata between the Hoosic mountain and the Hudson river, lie in an inverted order, drawings were exhibited, proving the existence of numerous closely-folded anticlinal and synclinal axes; and the inference was drawn, that the inverted dip of the rocks is the result of a folding of the beds at short intervals, and not of one general turning over of the whole series, as suggested by Prof. Hitchcock. Subterranean igneous action was referred to as having caused this compression and folding of the rocks, and its energy was shown to have been greatest along the Berkshire valley, and the ridges lying to the east. To the same agency was attributed the crystalline condition of the Berkshire marble, and of the associated schists and semi-vitrified quartz rock, the first being regarded as merely the blue limestone of the Hudson valley, extensively altered, and the last a highly altered form of the white sandstone at the base of the Appalachian formations.*

In the following April, Prof. Hitchcock, in his very able address

* See Proceedings of American Philosophical Society for January, 1841.

to the Geological Association, speaking of the remarkable apparent inversion of the dip, along the western side of New England, and through the Appalachian chain, no longer ascribes the phenomena simply to a toss over of the strata, but to a succession of folded axes, causing a high or more frequently an inverted dip on the western side. In another part he states, that although he does "not fully adopt, he cannot but look with a favorable bias upon this solution of the problem." In explanation of the manner in which the strata acquired this folded structure, he supposes that while yet in a plastic state, and but slightly elevated, they were acted upon by a force exerted in opposite directions, from near the Hudson and Connecticut rivers; and observes, that this force, "if powerful enough, might cause them to be folded up into several ridges, and if more powerful along the western than the eastern side, they might fall over so as to take an inverted dip, without producing any remarkable dislocation."

In the second edition of his Elementary Geology, published in August, 1841, Prof. Hitchcock, in discussing the phenomena, refers again to the theory of two forces acting in opposite directions at the two extremities of the strata, and suggests in addition the elevating action of gaseous or melted matter beneath, omitting, however, to account for the general southeasterly direction of the dip.

As the priority of our views in respect to the fact of an inverted and folded structure throughout the chain from Virginia to western Massachusetts, is, we think, clearly established, by our several publications above cited, we can only ascribe the omission, on the part of our esteemed friend, Prof. Hitchcock, distinctly to recognize it, to the insulated manner in which our descriptions and general views have appeared in our Annual Reports and other occasional publications.

Of the Flexures of the Strata, and the Law of their Gradation, from Southeast to Northwest.

The above-described phenomena of the dips in the Appalachian range may, we think, be readily accounted for by the peculiar character of the flexures of the strata. These flexures, unlike the symmetrical curvature usually assigned to anticlinal and synclinal axes, present, in almost every instance, a steeper or more rapid arching on the northwest than southeast side of every convex bend; and, as a direct consequence, a steeper incurvation on the southeast than the northwest side of every concave turn; so that, when viewed together, a series of these flexures has the form of an *obliquely undulated* line, in which the apex of each upper curve lies in advance of the centre of the arch. On the southeastern side of the chain, where the curvature is most sudden, and the flexures are most closely crowded, they present a succession of alternately convex and concave folds, in each of which the lines of greatest dip on the opposite sides of the axes, approach to parallellism, and have a nearly uniform inclination of from forty-five to sixty degrees towards the southeast. This may be expressed in other words, as a *doubling under or inversion* of the northwestern half of each anticlinal flexure. Crossing the mountain chain from any point towards the northwest, the form of the flexures changes, the close inclined plication of the rocks producing their uniformly southeastern dip gradually lessens, the folds open out, and the northwestern side of each convex flexure, instead of being abruptly doubled under and *inverted*, becomes either vertical or dips steeply to the northwest. Advancing still further in the same direction into the region occupied by the higher formations of the Appalachian series, the arches and troughs grow successively rounder and gentler, and the dips on the opposite sides of each anticlinal axis, gradually diminish and approach more and more to equality, until, in the great coal-field west of the Allegheny mountain, they finally flatten down to an almost absolute horizontality of the strata, at a distance of about one hundred and fifty miles from the chain of the Blue ridge or South mountain.

These general features in the physical structure of the Appalachian region, will be best understood by consulting the *Ideal section*, Plate XVI, intended to embrace the prevailing character of the different portions of the chain from the Blue ridge to the western coal-field. Along with this diagram, which embodies the general results of our observations, will be found several *actual sections*, comprising the principal details of structure and topography observed in different parts of the chain, from New Jersey to eastern Tennessee. These cross the belt at nearly equal intervals, and have been selected from a number, all of which equally exhibit the general conditions of structure above described.

To assist in conveying clear conceptions of the diversified and sometimes complicated modes of structure, occasioned by the flexures and foldings of the strata, we deem it important to introduce here two or three new descriptive terms, which seem called for by the necessity of possessing a phraseology adapted to the relationships of the strata about to be detailed. Using the terms anticlinal and synclinal in their commonly accepted sense, we propose to apply the phrases *anticlinal* or *synclinal* mountain or range, to designate ridges formed respectively by a convex and concave flexure of the strata. Every flexure, of such degree as to fall short of producing an inversion of the rocks on the northwestern side of the anticlinal, and the southeastern side of the synclinal bends, we shall call a *normal* flexure; and the dips corresponding to such flexures, as exhibited in transverse sections, we shall denominate *normal dips*. While the phrases, *anticlinal dip*, and *synclinal dip*, sufficiently express the directions of the beds, due to the concave and convex flexures, we propose the term *monoclinal*, to signify a sameness in the direction of the dip, and shall term a mountain or valley, in which such sameness prevails, a *monoclinal* mountain, or *monoclinal* valley. As briefly expressive of the whole concave and convex flexure, we propose to use the terms *arch* and *trough*.

Conceiving a plane to be extended through the apex or most incurved part of each of the concentric flexures in an anticlinal or synclinal bend, so as to occupy a medial position between the two branches of the curve, we propose to call this plane the *axis-plane*. Where the flexure is perfectly symmetrical on both sides of the plane, and the dip on the one side, therefore, equal to that on the other, it is evident, that the axis-plane will have a vertical position. In the Appalachian region, however, and, as we believe, in nearly all other disturbed chains, where the phenomena of flexure are exhibited on a scale of much extent, these planes are inclined to the perpendicular in a greater or less degree, according to the energy of the inflecting force. In the region before us, the dip of the imaginary plane is almost invariably to the southeast, the amount of the deviation from the vertical altitude diminishing progressively, as we cross the chain towards the northwest. A corresponding law of the axis-planes will, we believe, be found to obtain, in all extensive groups of axes, the general expression of their relation being, that the dip of the axis-planes is always *towards* the region of maximum disturbance. From the position thus possessed, by the axis-plane, it will readily appear, that its intersection with a horizontal line connecting the southeast and northwest branches of an anticlinal flexure, will lie nearer to the northwestern branch, and that the reverse will be the case in a synclinal bend. For these relations, see Diagrams, Plate XVI.

Character of the Flexures in each of the Nine Divisions of the Appalachian Chain.

While the flexures of the strata of the Appalachian chain every where conform to the general type above described, they display in each of its great subdivisions, some one or more prevailing characters, marking, as we think, the degree of energy, and the directions of the disturbing forces. Of these, as exhibited in the several divisions formerly specified, the following is a brief account.

1. *Hudson River Division.* In this belt, the flexures are, for the most part, of the closely folded type, and the dip is almost invariably towards the southeast, the compressed and oblique plication of the beds extending equally to the hypogene, or primary rocks, of the mountains bounding the valley on the east, and to the lower formations of the Appalachian system, which occupy the valley itself. Northwestward of the valley, this folded condition of the rocks gives place, as in the vicinity of the Catskill mountain, to flexures of the normal form, which, as we advance, become comparatively obtuse.

2. *Delaware Division.* In this curving district, the formations

of the valley, though still often inverted, are not always so, the flexures being less abrupt, and sometimes of the steep normal type. Thus, in New Jersey, in the tract chiefly occupied by the lower Appalachian limestone, the troughs become somewhat open, and admit long, narrow, synclinal belts of the next superior division, the great slate mass of the Hudson river. As we cross this division northwestward, beyond the valley, the flexures soon grow very gentle, and, as a consequence, the same rocks spread themselves out over very wide tracts, imparting to both the geology and topography a comparatively monotonous character. In all these conditions of flexure in this division, we detect the proofs of a less energetic uplifting and bending force, when compared with that which operated on the contiguous straight belts, situated to the north and south, where the close and oblique plications fill the valley, and where the steep normal flexures range further across the chain.

3. *Susquehanna Division.* Here the obliquely folded flexure is the prevalent one throughout the great valley, giving a general southeasterly direction to the dip. This inversion extends even to some distance northwest of the valley, so as to reach the first anthracite basin, in the middle or widest portion of which a southerly dip very generally prevails. The flexures or axes of this division occupy a very broad belt of country, extending from Lancaster county, across to the northern line of Pennsylvania, a space of one hundred and fifty miles.

4. *Juniata Division.* In this region, the strata are generally inverted, throughout the whole breadth of the South Mountain and the great valley. The principal anticlinal flexures of the Middle Mountain-belt, are remarkable for their great height and steepness, and for the frequency with which they bring almost the lowest of the Appalachian formations to the surface. These features, with the unusual breadth of the belt, across which the disturbances of the strata extend, would seem to show, that the forces producing the axes of this region were of unusual energy.

5. *Potomac Division.* This belt is remarkable for the straightness of its principal axes, and for the beautiful manner in which it exhibits the general laws of gradation in the flexures. Upon

its southeastern border, in the Blue ridge and great valley adjoining, there exists a general tendency to an oblique folding or inversion of the strata, though this condition is less predominant than in the two before-mentioned straight portions of the chain, namely, the Susquehanna and Hudson divisions. In other words, the rocks are less completely folded, many perpendicular and some northwestern dips occurring, to form the northwest side of the arches, and, as we advance beyond the valley, the normal curvatures become the prevailing ones. In accordance with this general condition of things, the great valley contains a long central belt of the middle Appalachian formations, included in a deep trough, a feature that could not exist, if the synclinal foldings were as compressed as in the other more inverted districts. This less closely folded state of the rocks appears to extend entirely across the whole undulated belt, the breadth of which, from the Blue ridge to the valley of the Monongahela, is about one hundred and ten miles. Such a feature seems to imply a less energetic disturbing force in this belt than in the district of curving axes adjoining it on the north, where the rocks in the valley are much inverted; and this inference is supported by the fact of the very rare appearance, at the surface, of those lower rocks, the older Appalachian limestone, for example, which occupy anticlinal tracts in the curving belt, and form a conspicuous feature of it.

6. *James River Division.* This district, sharing with the rest all their essential structural features, and displaying, as formerly mentioned, especially in its valley portion, much irregularity in the strike of its strata, and the direction of its generally short axes, is remarkable for a confused blending of the various kinds of flexure, even within a narrow breadth, and for the passage, more frequently than in the previous division, of the folded and inverted flexures into faults. The great valley is here occupied, in part, by the extensive synclinal range of the Short Hill, and the wide, irregular trough, including the Catawba and Fort Lewis mountains, as well as by other minor ridges of the superior rocks, and is marked by the occurrence of a long line of fault, accompanied by inversion, along the southeast side of the Fort Lewis mountain, and by the prolongation, in a variety of curious phases, of

the great fault, which extends along the southeastern base of the Little North or Brushy mountain, hereafter to be more particularly noticed.

7. *Holston Division.* In this region, the folded structure, attaining its maximum limits, assumes the new condition, (evinced, in a few cases, in the preceding district,) wherein the inverted flexures become a series of dislocations, surpassing, for their length, straightness, and parallelism, any other group of faults recorded. By far the greater part of the strata dip in one direction, or to the south-southeast, the downthrow at the faults being invariably on their northwest side. In crossing this region to the north-northwest, after passing for some distance to older and older formations as we approach a line of elevation, instead of meeting with their counterparts, in an anticlinal arrangement, we step at once from some of the oldest of the Appalachian formations, to beds as recent as the European carboniferous limestone, and thus behold in near contact, on opposite sides of the closed gulf, strata, which originally occupied positions in the vertical column, eight thousand feet apart. This abrupt transition may be noticed, many times in succession, in the first thirty miles, going northwestward from the base of the Blue ridge.

8. *Knoxville Division.* As in the instance of the district last described, the whole disturbed space is comparatively narrow. Here, too, in consequence of the numerous inverted flexures and parallel lines of dislocation, the strata are extensively inverted, having, therefore, very generally, a dip to the southeast, and displaying the normal form of flexure but rarely, until we reach the northwestern side of the district. Of this universal prevalence of southeasterly dip, mention is made by Professor Troost, in his 'Annual Reports on the Geological Survey of Tennessee, for the years 1839 and 1840,' and we can confirm his statements by our own observations, made in the northern parts of the district. An interesting feature in this belt, is the analogy which it displays to the other convex, or Juniata division, in the regular or uninterrupted curving of the axes and lines of strike; and, on the other hand, the decided contrast, in this respect, which they both pre-

sent to the two concave belts, where the axes are shorter and less parallel.

9. *Alabama Division.* This disturbed tract, progressively diminishing in breadth, from its commencement in Tennessee to its termination in Alabama, displays the usual inversion of the lower rocks, and the other signs of the presence of oblique flexures, and of that species of dislocation, which results from them, and would seem, from the best information we can collect, to preserve these features of structure without abatement to its extreme southwestern end, where it is finally overspread by the newer secondary and tertiary strata.

Thus, every section of the Appalachian chain, whatever its direction or curvature, offers the same remarkable and beautiful features and gradations in its axes, implying, that the cause of these phenomena was some grand and simple energy, coextensive with the whole margin of the Appalachian Sea, from Canada to Alabama.

Exemplification of the several Modes of Structure.

1st. *Normal Flexures.* Having presented a general outline of the different divisions of the chain, we shall next enter into a description of the several varieties of structure, which distinguish the different parts of it. Flexures of the normal character, constitute, as we have seen, the predominant curvatures of the strata, throughout almost the entire length of this mountain zone, the obliquely folded, or inverted axes, being principally limited to a belt of variable width, along the southeastern side. Of the numerous parallel anticlinal and synclinal ranges, which strikingly exhibit this normal configuration, we shall cite a few examples from Pennsylvania and Virginia, and refer to the engraved Sections accompanying this paper, for details of the dip in each respective portion of the chain. In the Knobly mountain, the most westerly of the great anticlinal flexures, situated to the southeast of the coal region, the normal character is maintained, with great uniformity, throughout a distance of upwards of fifty miles. It commences with the first appearance of the axis, in the immediate vicinity of Cumberland, and continues, as the mountain augments in breadth and height, in its extension to the southwest. Still further in that direction, beyond the intersection of the axis with the North Fork of the Potomac river, in Pendleton county, Virginia, the dips on the northwestern side of the arch become either perpendicular, or slightly inverted; and this attitude they retain for a further distance of about forty miles. Traced from its first appearance, a little southeast of Cumberland, to its termination in the anticlinal valley of Crab Bottom, this axis offers a beautiful illustration of the prevailing regular gradation, in the amount of inflection which the strata have undergone, in different portions of the line, as dependent on the varying intensity of the elevating and bending force. At first, the lowest rocks, which the axis exposes, are the red and calcareous shales (F. V,) or Clinton group. Here the flexure, though more abrupt on the northwest than on the opposite side, does not exceed a moderately steep normal curvature. Further to the southwest, where the next inferior formation (F. IV, Shawungunk grit) emerges to the surface, and expands, as we advance, giving an imposing breadth and elevation to the ridge, we find the northwestern part of the arch so increased in steepness, that its dips are nearly vertical. The axis, becoming still more developed as we proceed, the next inferior formation (F. III, Hudson slates) now makes its appearance, and rapidly expands into an anticlinal valley, which separates the broad and lofty mountain range into two distinct ridges. The strata of the northwestern of these crests have a vertical, and even, sometimes, an inverted dip. Still further, in the same line, a yet lower formation rises, the great lower Appalachian limestone (F. II), and occupies a large portion of the breadth of this anticlinal valley. The dip of the rocks in the northwestern ridge now becomes, as might be anticipated, very frequently inverted. Passing this culminating portion of the axis, its further prolongation to the southwest is marked by the foregoing phenomena, in a converse order, until finally, near the head-waters of Back Creek, the divided strata of the higher groups once more unite, to form a gentle normal flexure, in the inconspicuous ridge at the southwestern termination of the axis.

In the *Bull Pasture* mountain, which traverses Pendleton and a portion of Bath counties, in a line southeast of the range above described, we have an example of the retention of the normal structure throughout the entire length of the axis, embracing a distance of more than fifty miles. Here, also, we witness the gradual steepening of the flexure, as lower and lower groups are elevated to the surface, although the whole amount of the elevatory movement, having, in this case, been less than in that of the Knobly axis, it has nowhere produced an actual inversion of the dip.

The interesting relation here disclosed between the steepness of the flexure, and the amount of actual rise of the rocks, at different points in the axis, extends to all the shorter, as well as the most prolonged of these lines, and applies to every part of the Appalachian chain, constituting a law of structure, connected intimately with the theory of the nature of the folding movement.

Besides the above cases, we may cite, for Pennsylvania, the great axis of Wills's Creek mountain, that of the Black Log anticlinal valley, and the still more prolonged one of the Kishicoquillas valley, and Jack's mountain, in all three of which the normal type is preserved, while the relation between the degree of developement of the axis and the steepness of the northwestern dips, as already announced, is uniformly displayed.

2nd. *Inverted Flexures.* As indicated in the general or ideal Section of the chain, the flexures, accompanied by an inversion of the strata on the northwestern side, are of most frequent occurrence along the southeastern border of the Appalachian chain. In some districts, however, these foldings extend, for a considerable distance, across towards the middle of the belt, a fact well exemplified in the general southeasterly dip of the Pottsville coal-field. The passage from the normal to the closely folded inverted curvature, as the developement of the axis increases, is a phenomenon well observed in a number of the principal anticlinal ranges in Pennsylvania and Virginia, among which may be instanced the Bald Eagle axis, in the former State, and the Jackson's mountain and the Wolf creek axes, in the latter.

The Bald Eagle axis, commencing some miles south of Hollidaysburg, and ranging west of the centre of Sinking and Nittany valleys, and through the middle of Nippenose valley, terminates south of the Allegheny mountain, a number of miles northeast of Pennsboro'. It thus embraces, in its long and gentle sweep, a distance of about one hundred and twenty miles. For many miles of its length, at each extremity, where it lifts only the middle Appalachian rocks, it displays simply a gentle normal flexure; but nearer the middle of the line, where it elevates lower and lower formations, and finally brings to the surface the great Appalachian limestone, the arch gradually steepens, until it embraces a vertical, and occasionally an inverted dip, along the Bald Eagle mountain, from the Little Juniata to Bellefonte.

The Jackson's mountain axis commences near the northwestern flank of the Fork mountain, in Pendleton county, Virginia, and continues in a nearly straight direction in Jackson's mountain, and the anticlinal valley of the Warm and Hot Springs, as far as Jackson's river, in the neighborhood of Covington. This comprises a length of about seventy miles. Traced from its northeastern extremity to within a few miles of the first exposure of the lower Appalachian limestone, the mountain continues single, and displays a normal, but regularly increasing arch, with a steepening northwest dip. But further towards the southwest, from the commencement of the anticlinal valley, in which the limestone rises, to the lower end of the Falling Spring valley, the mountain divides itself into two ridges, that on the northwest exhibiting both perpendicular and inverted dips. Beyond the Falling Spring, the valley rapidly closes up again by the subsidence of the axis, and at Jackson's river nothing remains of this remarkable range but a low ridge, composed of the higher rocks, arching over in a moderately obtuse normal flexure.

The Wolf creek axis, in Virginia, rises near the head of Stony creek, a little southeast of Peters's mountain, and ranges along the southeast side of Peters's, and the northwest side of Wolf creek mountain, and Rich mountain, for a distance of between seventy and eighty miles. Throughout nearly the whole of its length, this axis lies in the lower Appalachian limestone, in which there is an inversion of the dip on the northwest side of the axis.

plane, that sometimes passes into a fault. This inversion is strikingly displayed along the southeastern base and slope of the synclinal mountain, called Buck-horn ridge, adjoining the axis on the northwest, where the strata of this side of the mountain are folded over so as to lie in almost parallel posture with the corresponding rocks on the opposite or northwestern side of the trough.

3rd. *Flexures broken, or passing into faults.* A feature of frequent occurrence in certain portions of the Appalachian belt, is the passage of an inverted or folded flexure into a fault. These dislocations, preserving the general direction of the anticlinal axes, out of which they grow, are usually prolonged to a great distance, having, in some instances, — for example, in southwestern Virginia, — a length of about one hundred miles. These lines of fault occur in all cases, along the northwestern side of the anticlinal, or the southeastern side of the synclinal axis, and never in the opposite situation. This curious and instructive fact is best seen by tracing, longitudinally, some of the principal anticlinal axes of Pennsylvania and Virginia. From a rapidly steepening northwestern dip, the northwestern branch of the arch passes through the vertical position, into an inverted or southeastern dip; and at this stage of the folding, the fault generally commences. It begins with the disappearance of one of the groups of softer strata, lying immediately to the northwest of the more massive beds, which form the northwestern summit of the anticlinal belt. The dislocation increases as we follow it longitudinally, group after group of these overlying rocks disappearing from the surface, until, in many of the more prolonged faults, the lower limestone is brought, for a great distance, with a moderate southeasterly dip, directly upon the carboniferous formations. In these stupendous fractures, of which several instances occur in southwestern Virginia, the carboniferous limestone being brought into close proximity to the great lower Appalachian limestone, a portion of which, even, is occasionally buried, the thickness of the strata ingulfed cannot be less than seven thousand or eight thousand feet.

The position of the strata along some of these extraordinary dislocations may be seen in the Sections C, D, E, (Pls. XX, XXI,) accompanying this paper. Sections D and E represent (at *a*) the conditions prevailing in the prolonged fault on the northwest side of the axis of the Sweet Spring Valley. This axis, in its normal state, brings up the great lower Appalachian limestone, flanked on the northwest by the overlying slate and sandstone, which, together with the northwestern half of the limestone, have a steep northwestern dip. More towards the southwest, this dip augments; the strata on the northwest side of the axis soon become vertical, and thence quickly pass into the inverted position. At this point, the fault begins, being marked, at first, by the disappearance of a portion of the slates (For. III) and variegated shales (For. V), adjoining the thick-bedded sandstone (For. IV), which forms the framework of the ridge, that bounds the anticlinal valley on the northwest. It presents, as it extends southwestward, a continually augmenting hiatus in the geological series, ingulfing in succession nearly all the strata between the limestone of the axis, and the carboniferous limestone, and exhibiting an inversion of the latter, for some distance across to the northwest of the line of fault. The inversion of the strata near the dislocation on its northwest side, giving them a southeasterly dip, becomes less as we recede from the fault. By a gradual transition, the dips become perpendicular, then steeply inclined to the northwest, and eventually, at no great distance, very gently so; after which, a few broad and feeble undulations succeed, as we pass into the coal region. Tracing this line of fault, in a southwesterly direction, for a distance of upwards of one hundred miles, we encounter, at various points, portions of the ingulfed strata, which occasionally reappear to form isolated knobs or short ridges, inclosed between the two great limestone formations (F. II, and F. XI), the crushed edges of which, however, are usually not thus separated. The detached masses, so curiously wedged into the chasm of the fault, consist of small remnants of the thick slate group, which underlies, at some interval, the carboniferous limestone, and of the hard white sandstone (F. IV, Shawungunk grit), which constitutes, as it were, the bony skeleton of our principal Appalachian ridges.

Sections C, D, and E, show (at *c*) the conditions usually prevailing in a very remarkable line of fault, which extends, with but few interruptions, along the western margin of the Great Valley of Virginia, throughout the chief part of its length. The ridge, which bounds this valley on the northwest, and which, as we pursue it southwestward, assumes successively the names of Little North mountain, North mountain, and Brushy ridge, marks the position of this extraordinary dislocation. With the exception of several intervening spaces, some distance south of the James river, in which the normal, or northwestern dip of the rocks in this ridge is in the main retained, its strata assume an inverted attitude, the great lower Appalachian limestone of the valley, lying on the slates of the next superior group, and these, in turn, resting with a southeast dip on the white sandstone, while the adjoining formations of a still higher position in the series, are either partially or entirely swallowed in the fissure. The sandstone itself, which, throughout a part of the State, gives prominence to the ridge, and the slates intervening between it and the limestone, are both more or less ingulfed; and, in some parts of the line, the whole mass of the mountain has disappeared; so that the observer may cross, by a single stride, from the very ancient limestone of the valley, to beds but little lower in the series than the carboniferous limestone. Still further along the line, the formations thus lost are seen partially rising again into view, the white sandstone (F. IV) first showing itself in insulated knobs or patches, and afterwards in a continuous, low, and irregular ridge, in which some of the other missing groups also reappear. Between a point a few miles south of the intersection of the James river with this ridge, and the neighborhood of Abingdon, near the Tennessee line, this fault assumes a more uniform, though, perhaps, a still more extraordinary character. At the passage of the river, the massive range of the North mountain presents no other indications of this line of fault than a partial inversion of the thick beds of sandstone, of which it principally consists, and an entire overthrow and partial burial of the slates which flank it on the southeast. But a few miles further towards the southwest, the whole of this enormous mountain mass sinks from view, excepting an isolated knob here or there, of the harder rocks, which, for a short distance, serve to mark the irregular progress of the fault. At length, the dislocation attains what may be called its maximum intensity; the slate, and not unfrequently, the limestone of the valley, resting in an inverted attitude, with a gentle southeast dip, directly upon the southeasterly dipping grits and shales of the formation next beneath the carboniferous limestone, here constituting the southeastern slope of the Brushy mountain. The seam of semi-bituminous coal, generally embraced between these strata, is, in virtue of the dislocation, made to assume the anomalous condition of passing *under* the valley limestone at a distance of only a few hundred feet, dipping in the same direction with that rock.

Preserving these features, with but little variation, throughout its whole course to the southwest, this extraordinary fault extends, in an almost perfectly straight line, along the southeastern slope of the Brushy mountain, from near the head of the Catawba creek, to the vicinity of Smyth court-house, a distance of more than eighty miles. At no point, in this line, are the rocks which originally formed the counterpart to the strata of the Brushy mountain, and which are, in fact, represented by those of the Little North mountain, in the northern part of the line, even partially restored to the surface; so that this stupendous dislocation is to be viewed as having actually swallowed up the rocks of the southeastern half of a large synclinal basin, of which the Brushy mountain remains as the other half.

4th. *Of the distribution of the axes in groups.* Wherever, in the Appalachian chain, we become minutely familiar with the undulations of the strata, we find it impossible to resist the conclusion, that the axes arrange themselves in natural *groups*, the individual flexures showing a close agreement in their length, mutual distance, straightness, or curvature, and in the extent and style of the arching. In those districts which are crowded with normal axes, such as the Susquehanna and Juniata divisions, many such groups attract our notice. Each of these assemblages of axes being generally distinguished by some special character, we are inclined to regard the comparison and analysis of their several features as of the very highest importance, in those investigations of geological dynamics into which the whole subject of flexures must evidently lead us. The limits of the present memoir preclude a detailed description of each group of axes, contained even in the States of Virginia, Pennsylvania, and New Jersey, where we have principally explored them, and altogether forbid any attempt to apply our theory of flexures to an explanation of the local features, distinctive of each group. We shall, therefore, content ourselves with describing two or three of these collections of axes, more for the purpose of proving our present general statement, that the axes do thus assort themselves, than with a view to discuss the secondary causes connected with their peculiarities.

The great divisions, into which the entire chain naturally divides itself, are alone abundantly significant of this essential tendency of the axes to form groups. For, upon a general view of the whole chain, each of the nine extensive belts, into which we have divided it, becomes one comprehensive group, in which all the axes display certain common characteristics of straightness or curvature, as the case may be. Lest, however, it should be supposed, that this grouping of the flexures is only to be recognized when we embrace very extensive subdivisions of the chain, we shall refer to smaller tracts, and show, that axes of all dimensions thus associate themselves. An excellent instance of a group is to be seen in a district composed of the northern half of Mifflin, and the southeastern half of Centre counties, in Pennsylvania. The axes which belong to the general convex system of the Juniata accord remarkably, in all their essential features. They are either of the normal type, with steep northwestern dips, or they have the northwestern part of the arch slightly inverted. They are almost exactly parallel, curving a little in obedience to the general sweep of the chain, while they are singularly equidistant from each other. As each flexure possesses nearly the same transverse form and dimensions, they bestow a strikingly regular and symmetrical topography on the whole region, the great lower Appalachian limestone and slate groups rising to the surface in a series of long and parallel anticlinal valleys, while the overlying sandstones compose so many intervening, steep, straight, and regular synclinal ridges.

Another well characterized belt of flexures fills the Lewistown valley in Pennsylvania; applying this name to the whole of the long, natural valley, which extends from the Susquehanna to the Juniata, southeast of Jack's mountain. In a breadth of about six miles, there are here usually from five to six long, parallel, and gently curving anticlinal axes, all of them of the normal form, resembling each other very nearly in the steepness of the dips, or average degree of flexure. The lowest rocks, which they lift to the surface, are the variegated shales, (F. V, Clinton group,) and the highest, which their intermediate troughs have retained, are the sandstone (F. VII,) and the overlying slates of F. VIII.

A third very natural group of flexures is to be noticed in the eastern part of the middle anthracite coal-field of Pennsylvania. The axes in question separate that region into an assemblage of small, parallel coal basins, of which the Beaver Meadow basin is one. Like the previous groups, these axes are characterized by their remarkable parallelism, their similarity in length, their exact equidistance, and their gentle gradation, approaching to equality, in the degree of the flexure. They all of them bring to the surface the conglomerate which next underlies the coal, and the troughs, which they form, contain about the same moderate depth of coal measures, growing shallower, however, to the northwest. This collection of axes, unlike the two groups before described, belongs to a straight system.

If it were desirable, we might extend the enumeration of the groups of axes to every part of the Appalachian chain; but abundant evidence has been furnished, to show that our anticlinal axes are not irregularly distributed, but maintain relations with each other, which require that they should be classified and studied collectively. Their generic resemblances examined, they will be found to exhibit general laws and analogies, that cannot fail to lead to some highly curious results concerning the forces, which from time to time have thus undulated the earth's crust. That this curious and most instructive department of geological dynamics has escaped, until lately, the attention of the best investigators, we can only attribute to the fact, that in Europe, no belt of axes, equal in extent to the Appalachian system, has come within the notice of geologists. Before a philosophical theory of flexures can be framed, large opportunities must be had for classifying their phenomena, and tracing their laws of gradation.

It is a curious and important fact, connected with this group of axes, that in certain cases, chiefly, we believe, in wide and deep troughs, the included smaller axes or wrinkles, though parallel to each other, are not parallel to the general synclinal axis of the basin, in which they occur. This feature is obvious in all the deep anthracite coal-basins of Pennsylvania, especially near their terminations. These lesser, subordinate axes, generally have a strike parallel to that of one of the great flexures bounding the basin; but, on account of the convergence of the sides of the trough, they are necessarily more or less oblique to the opposite margin. They are, therefore, so many long, parallel warpings of the strata, conforming to one boundary, but abutting acutely against the other. Sometimes, indeed, they cross the basin very gradually, or pass almost longitudinally, from one side to the opposite, and die out, as wrinkles on the slopes which bound the basin. That they have originated in an inequality in the energy of the linear forces concerned in bending and elevating the rocks along the principal flexures, and arise, therefore, from an actual warping of the strata, seems altogether probable. If so, they are secondary consequences of those more general and extended movements, which give existence to the grander flexures, in whose folds they lie. To describe all the phenomena relating to these minor assemblages of axes, the full investigation of which, as it concerns the mining operations of our coal-fields, is, perhaps, the most useful practical inquiry that the geologist can undertake, would demand a body of minute details, only to be elucidated by a general map of the flexures, not yet ready for publication.

5th. *Parallelism of the axes in each group.* The parallelism of the several axes or lines of flexure, which compose a group, either extensive or limited, is one of the most remarkable relations. The descriptions already furnished show, that it prevails in every portion of the chain, whether straight or curved, and extends even to the members of the smallest groups. A striking exhibition of this mutual parallelism may be noticed among the inverted and normal flexures in the great valley, in that part of the chain which we have called the Potomac division. Some of the larger axes are there prolonged, side by side, for nearly one hundred miles. The same fact may be equally well seen in the great curving axes of the Juniata division, and amongst those most remarkably persistent flexures, which divide the parallel bituminous coal-fields northwest of the Allegheny mountain, in Pennsylvania and Virginia. It is yet more strikingly displayed, perhaps, in the long and singularly straight axes and faults of the Holston region, in Virginia and Tennessee, where the lines, both of flexure and of dislocation, maintain almost exactly the same distance from each other for upwards of one hundred and fifty miles. This parallelism, however, is after all but approximate, though, as many of the adjacent axes of a group in a length of say fifty miles, observing a mean distance of not more than two or three miles, seldom approach or recede more than a fourth of this space, we are justified in seeking for some theory which shall explain so conspicuous a relation.

6th. *Of the great length of some of the axes.* Perhaps nothing astonishes the geological traveller in the Appalachian chain, so much as the enormous length and persistency of many of the axes. Tracing these lines of flexure longitudinally, they will not unfrequently be found to range for eighty or one hundred miles, with but little deviation either from perfect straightness, or from a uniform gradual curvature, parallel to the general inflection of the division of the chain, in which they are included. This astonishing regularity and length is, perhaps, best noticed in the axes of the northwestern side of the belt, where they frequently exhibit a steady curvature, for more than one hundred and fifty miles. Whether the southeastern axes are less prolonged, or whether their crowded condition often conceals the continuity of their range, are points we do not at present undertake to decide. Among the very numerous instances of long and regular axes of the steep normal type, we must specify, in the Susquehanna region, the straight axis of Montour's ridge, which extends about eighty miles; in the Juniata division, the beautifully inflected axis of Jack's mountain, continuous for more than ninety miles; in the Potomac division, the straight axis of Wills's creek mountain, ninety miles in length, and also that of the Knobly mountain, nearly a prolongation of the last, itself a hundred miles long. To these we may add, for the Holston region, the straight axis of Wolf creek, and that of the Clinch mountain, the former of which is about one hundred miles, and the latter more than one hundred and twenty miles in length.

It is probable, that numerous axes of the folded or inverted type, quite as extended, exist in the great valley, and the adjacent belt of ridges on the southeast side of the chain, and we have already seen, that where some of the steep normal and inverted flexures pass into dislocations, they have a length even exceeding that of any of the axes above referred to. If we turn to the more depressed normal axes of the western coal region, we shall find, that that which lies next northwest of the Potomac basin, is at least seventy miles long, that of the Negro mountain ninety miles, that of Laurel hill at least ninety miles, and that of Chestnut ridge, or West Laurel hill, more than one hundred miles in length; and our geological maps will exhibit, in other less well-known portions of the same belt, a series of similar obtuse flexures, of even still more extended length.

7th. *Of the curving of axes.* It is needless to add much to what has already been said or inferred concerning the horizontal inflection of the axes in some groups, since the changes of strike mentioned, while tracing the great divisions of the chain, involve a parallel bending of all the principal and most influential flexures individually. Considering the enormous extent of *warping*, which the crust must have undergone, and which we can infer that it did undergo, from the evidence afforded in the lesser, or secondary flexures, and also from the nature of the faults, the prevailing continuity and graceful, curving outline, witnessed in many of the inflected axes, are truly remarkable. There are cases, as in that of the Jack's mountain flexure, where a continuous axis sweeps for ninety miles, to undergo a change of strike of as much as forty-five degrees, without once taking on a serpentine or contrary incurvation, or manifesting any considerable inequality in the bending. Instances of such extraordinary length and regularity, are, however, comparatively rare, and are confined chiefly to the divisions of the chain in which the curvature is convex to the northwest. A more common linear form among the longer curving axes, if we except those, — the longest and most regular of all, — which traverse the great northwestern coal region, is one which embraces a partial discontinuity of the line, at one or several points. This discontinuity is, in most cases, only partial, being of the nature of a warp, the anticlinal arch embracing, generally on its southeastern slope, another flexure, which either immediately, or at a moderate distance, becomes the principal, and finally the only, anticlinal crest, while the original summit, in its turn, subsides upon the flank of the other. In such cases, where the two closely overlapping flexures are included within one general anticlinal arch of about the same average breadth and height as the parts which contain the flexure in its single state, and where the relative depression embraced by the warp is comparatively trivial, there seems no impropriety in considering the whole as one great undulation, locally disturbed, from some inequality in the bending or resisting forces. The warp will, in fact, be found, in such cases, to occur commonly near the central portion of the line, where the maximum degree of flexure and elevation, in all strictly continuous axes, has been experienced, and exactly where we would naturally look for the greatest irregularities in the movement of the strata.

When the bearing of the various phenomena of curving axes upon some of the most interesting questions of geological dynamics is contemplated, the importance of a critical investigation of all their modifications of form cannot fail to be recognized. Besides demanding their proportion of attention, in any theory which attempts to explain the origin of axes, generally, these curving axes of our Appalachian region merit particular examination in another light. They appear to contradict directly the well known hypothesis of the distinguished French geologist, M. Elie de Beaumont, which supposes, that a constant relation subsists between the epoch of elevation, and the directions or strikes of the lines of disturbance. These curving axes constitute so many intermediate links between the straight divisions of the chain, in which they terminate at their opposite extremities, and they are demonstrably of the same age with the rectilinear flexures, with which they there alternate. But the different sections of the chain, thus referred to one general succession of elevatory movements, differ from each other in their strike as much, in some instances, as forty or forty-five degrees; and, if we include systems of axes not contiguous, but the sameness of whose date is equally demonstrable, — as when we compare the Vermont and the Holston axes, — the difference in direction is even as much as sixty degrees. Here are extensive mountain belts, each upwards of two hundred miles in length, possessing unequivocally the same epoch, differing in the direction of the elevatory movement much more than some of the European systems of widely different geological age. It is obvious, then, that the generalization of M. de Beaumont, if in accordance at all with nature, is only so as it relates to the general direction of entire mountain systems, and not to the course of special groups of axes, however extended.

Description of a Series of Sections across the Chain.

Section A, (Pl. XVIII.) This Section extends from the South mountain, in Berks county, Pennsylvania, through the anthracite basins, to the Allegheny mountain, in Luzerne county, and exemplifies the usual features of structure prevailing in the Susquehanna division of the chain, showing the folded and inverted condition of all the rocks in the South mountain and great valley, also the steepness of the northwestern sides of the flexures in the rest of the belt, and the beautiful grouping of the axes, especially in the middle anthracite region, combined with a general progressive reduction in the abruptness of all the curves and dips. It likewise shows, that the hypogene strata of the South mountain are included in the same general system of flexures with the Appalachian strata.

Section B, (Pl. XIX.) This extends in a west-northwest direction, from the South mountain, in Cumberland county, Pennsylvania, through the Broad Top coal-field, to Chestnut ridge, in

Indiana county, and offers a striking illustration of the existence of exactly the same structural features, in the curving region of the Juniata, as the other shows in the straight one of the Susquehanna. The folded or inverted axes occupy the belt of the South mountain and great valley, northwest of which they are succeeded by a broad belt of steep normal flexures, several of which lift to the surface nearly the lowest formations of the system. This Section also displays the manner in which the western coal region is divided by the wide and gentle flexures northwest of the Allegheny escarpment.

Section C, (Pl. XX.) Our third Section crosses the chain in a direction from the Blue ridge, at Ashby's gap, in Virginia, through Winchester and Romney, to the commencement of the coal rocks, on the Front ridge of the Allegheny mountain. It exhibits normal flexures everywhere but in the Blue ridge and great valley. In the Short hill and Blue ridge, at the southeast end of the Section, the sandstones, forming the lowest group of the Appalachian system, are seen in folded anticlinal flexures, which equally affect the older metamorphic rocks, the whole of the northwestern slope of the Blue ridge presenting an inverted or southeastern dip. The general southeasterly inclination of the axes-planes, or, which is the same thing, the greater steepness of the northwestern, compared with the southeastern dips, is very uniformly exhibited in this Section. The rocks of the Little North mountain are here shown to be inverted, presenting (at *c*) one of the phases of the prolonged fault, formerly alluded to.

Section D, (Pl. XXI.) This Section crosses the chain from a point high up on the south fork of the Roanoke river, in Virginia, to the northwest base of the Peters's mountain, near Union. Lying in the James river division of the chain, it exhibits the rather confused mixture of normal and inverted flexures and faults, for which that district is remarkable. On the southeast, are seen the bold flexures of the strata of the lowest of the Appalachian formations, here of extraordinary thickness, and forming a lofty mountain range, while, immediately behind them, on the southeast, are seen the numerous foldings of the ancient metamorphic strata. A fault (at *d*) at the southeast base of the

Fort Lewis mountain, shows Formation II thrown over upon VIII. Some miles towards the northwest (at *c*) is the great fault of the Little North mountain, presenting Formations II and X, in contact, the former being uppermost. Near the northwest termination of the Section (at *a*) is seen the fault on the northwest side of the Sweet spring, or Peters's mountain axis, here showing the contact of For. II with the upper part of For. VIII; the remainder of the latter, together with the other intervening formations, being lost. In this part of the Section may be seen the rapid passage of the higher rocks, from inversion to verticality, and thence into a very gently undulating and horizontal position, towards the northwest.

Section E, (Pl. XXI.) This Section extends from the Poplar camp mountain, in Virginia, near the mouth of Reed creek, in a north-northwest direction, to the commencement of the coal rocks, immediately northwest of Abb's valley. Lying in the Holston division, in the southwestern part of Virginia, it traverses nearly all the great parallel lines of fault, for which that region is so remarkable. At its southeastern extremity we notice the lowest formation of the Appalachian system, bent over into an inverted position, and resting upon the next superior rock, the great lower limestone, (For. II.) Steep normal, and also folded flexures, extend across the valley to the Cove mountain, at the southeast base of which we meet with a line of fault (at *d*), bringing in contact Fors. II and VIII, with the usual inversion of the former. Beyond this, to the northwest, near the southeast base of Brushy ridge (at *c*), is the great dislocation referred to on previous occasions, and which here brings together Fors. II and X. Still further towards the northwest, in the valley of Walker's creek, on the northwest side of an inverted anticlinal axis of For. II, a similar fault occurs (at *b*), with the same hiatus of the intervening formations. Beyond this, or northwest of the Wolf creek axis, we see (at *a*) an extension of the great fault previously described as running along the northwest side of the Sweet spring, or Peters's mountain axis. A few miles further, we come upon the last, or most northwestern line belonging to this division of the chain.

Increasing Interval between the Axes as we advance Northwestward.

It is an interesting general fact, that the space between the axes, or, more properly, the amplitude of the undulations, increases as we cross the chain northwestward. This is represented in the ideal Section, and is equally apparent in the actual Sections which accompany it, being strikingly visible in that (Section B) intended to illustrate the structure of the Juniata region. Although distinctly noticeable in the northwestern side of the belt, the gradation prevails equally in the middle and southeastern tracts, though in the latter the numerous minor flexures, with the interference of groups of different dimensions, prevents our at first perceiving the law in all its simplicity and exactness. Towards the southeastern side of the chain, the flexures become so numerous, and are so often folded or inverted, as, in most cases, to render the comparison of their distances impracticable. Yet, even in this quarter, the general truth appears, in the diminished space between the foldings, as we cross the Great Valley, southeastward. Taking in the whole breadth of the chain, the prevalence of the rule is obvious, no matter by what Section we cross.

PART II.

Theory of the Flexure and Elevation of the Strata, founded on the preceding Phenomena, — combined undulatory and tangential Character of the Movement.

That the movement which produced the permanent flexures was compounded of a wave-like oscillation, and a tangential or horizontal pressure, both propagated northwestward across the disturbed belt, is plainly indicated by the oblique character of nearly all the anticlinal and synclinal curves, both those which are closely folded, and those which are obtuse. This oblique inflection of the strata will, we confidently believe, be found to prevail as the regular form of all anticlinal axes, in every part of the world. It appears to imply a powerful tangential movement, always operating in the same direction for the same region, during the epoch of disturbance. A merely vertical force, exerted either simultaneously or successively, along a system of parallel lines, could only produce the same number of *symmetrical* anticlinal arches, while again, a horizontal or tangential pressure, uncombined with an alternate upward and downward motion, at regular intervals, could not possibly result in a system of parallel folds, or axes, or lead to any change in the position of the strata, beyond an imperceptible bulging of the whole tract, or else a confused rumpling and dislocation, dependent on local inequalities in the thickness or resistance of the crust, in different spots.

That the *wave-like* flexures of our Appalachian strata are the result of an actual *onward, billowy movement*, proceeding from beneath, and *not* of a folding due simply to some *great horizontal or lateral compression*, will appear from the following considerations. In the first place, it is absolutely impossible to conceive, that *any* force, of an intensity however vast, exerted in the direction of a tangent to the earth's surface, could by itself shove a thick and imperfectly flexible crust into a system of close *alternate* folds. Beyond the imperceptible bulging of the whole tract laterally from the line of application of the force, no flexure could arise, other, perhaps, than some diminutive, but *irregular* plications, caused by inequalities in the strata or crust, and these, it is needless to remark, would be destitute of any law of parallelism and gradation, such as that which strikingly characterizes the Appalachian and other regions. No *system of narrow waves* of the strata, however flat, could originate from the most enormous lateral pressure, if unaccompanied by some vertical oscillation, producing parallel lines of easy flexure. Precisely such an alternate movement would ensue, if a succession of *actual waves* on the surface of the subterranean fluid rock rolled in a given direction beneath the bending crust.

The inadequacy of the tangential or horizontal force, as a cause of the Appalachian axes, is still further obvious, when we consider, that no igneous rocks, of any sort, were thrust to the surface, except in the belt of country bordering this broad system of flexures on the southeast, and that, therefore, if the axes or foldings were produced solely by lateral pressure, the whole force must have been propagated from the lines, where the wedging in of the igneous matter occurred in this southeastern region, to the remotest of the axes, through all the intervening folds. But, consistently with mechanical analogies, such a transmitted force, instead of producing the gentle gradation of flexure, which we behold, would have expended itself in merely compressing or crushing the contiguous tracts across a narrow belt, a little widened by a succession of these tangential actions. The narrow disturbed belt would abound in irregular contortions, and beyond it we should suddenly come to the strata in their original horizontality.

That such would really be the effect of the supposed horizontal action, is clearly proved by the singularly undisturbed condition, already stated, of the strata immediately, and for some distance, northwest of all our great lines of dislocation. Along these lines, the uniform inversion, and the crushed and contorted state of the higher rocks, immediately northwest of the fracture, indicate plainly an enormous lateral thrust in that direction from the fault. Yet, even where the greatest energy of this force is manifested, the inversion or other disturbance extends only for a few hundred yards northwest of the fissure, while a little beyond, the horizontal posture of the rocks has been even less changed than in parts of the same region, where no fault exists.

Even granting, that such a force, transmitted to a great distance across the chain, were capable of bending the strata of the remoter tracts into gentler undulations, the flexures on their northwestern sides ought to be relatively still steeper than they are, for in that quarter the curves are almost symmetrical. On the other hand, this near approach to a symmetry of curvature in the remoter axes, is an obvious consequence of the greatly reduced force and size of the nearly exhausted waves.

The widening of the interval between the axes, as we go to the northwest, is another general fact, which, while it finds a ready explanation in the hypothesis of a violent undulation of the strata, would seem to be wholly at variance with the operation of a gradual and prolonged pressure, exerted northwestward. Conceiving the various degrees of inflection witnessed in different parts of the chain to have resulted from a long-continued pressure, we should be compelled to admit, that the southeastern side of the tract had had impressed upon it successively all the different gradations of flexure met with throughout the chain, and thus we should have to suppose, that the closely folded, crowded axes of the great valley were slowly developed by a force that, in its earlier stages, produced every where only wide and gentle arches. Yet, if such was the case, why do we not recognize a yet more uniform or gradual transition in the dimensions of the axes, than our Sections show. If the steepness of the flexures measures thus their age, why, it may be asked, are those of the same group so various in this respect, while their intimate relations to each other, in respect to parallelism, gradation of distance, and dip, plainly prove them to have had a contemporaneous origin? If a long period was consumed in their production, why did there not take place, by virtue of the simultaneous denudation and deposition which must have been in progress, a constantly unconformable superposition of the new deposits, as the axes slowly rose above the level of the water?

But, while the observed variety in the magnitude and steepness of the flexures thus makes it incumbent on the advocates of such a theory of the gradual formation of axes, to admit, that the folded and closely crowded ones have arisen out of broader and normal curves, the general tenor of their doctrine of progressive and cumulative actions, implies, that the short and narrow flexures were produced first, and that some of them were enlarged into the vastly bolder and longer axes, which abound in many parts of the same region. This, however, seems an insuperable difficulty, since, if we suppose the breadth and length thus steadily to increase, a great number of intervening flexures and foldings would be necessarily obliterated or reversed.

But, quitting the theory of a gradual horizontal pressure, another hypothesis suggests itself, as likely, in the present stage of geological speculation, to be offered in explanation of the structural laws we have described. It may be urged, that *a* *prolonged upward tension, or pressure exerted along a single line,* might gradually create a broad and lofty anticlinal flexure, and might, *by a mere shifting of the line,* into positions always parallel to its first one, accomplish in time the elevation of all the axes of any of our Appalachian groups. Such a supposition would, doubtless, account for the simple features of a symmetrical flexure; but it would afford no clue to an explanation of those beautiful relations, which prevail between the form of the flexures and their position in the groups, to which they appertain, or to the fact of their assemblage into groups; and these are among the most interesting general facts, which a theory of flexures is called upon to explain. How could a merely vertical force, applied to the interior surface of the crust, either along a narrow line, or over an elongated elliptical, narrow zone, produce that *oblique* form of the anticlinal arch, which we find to be its normal configuration; or how could it give rise to the regular *horizontal bending of the axis-line,* as seen in the curving districts of the chain. Again, in what way can it explain the occurrence of the great lines of fault only on the northwestern side of the axes, or the close oblique foldings, in all the southeastern side of the belt. But, apart from all these objections, on what principle or analogy are we entitled to assume, that the supposed successive shifting of the upward force *would be* in parallel lines. Should the elevation theory be modified so as to suppose the upward force to have been exerted simultaneously along all the present anticlinal lines, but not in the manner of an undulation, the equally formidable difficulty arises of accounting for the production of *any* flexures; since, by the close contiguity of the parallel lines of upward pressure, the sole effect would be a nearly uniform diffused bulging of all that portion of the crust, upon which the tension was exercised.

Of the Origin of the supposed Subterranean Undulations, and of the Manner in which the Strata became permanently bent and dislocated.

The parallel flexures of the crust, so strikingly exhibited in the Appalachian chain, and recognizable, we believe, in nearly all disturbed mountainous districts, we conceive to have originated in the following manner. We assume, that in every region, where a system of flexures prevails, the crust previously rested on a widely extended surface of fluid lava. Let it be supposed, that subterranean causes competent to produce the result, such, for example, as the accumulation of a vast body of elastic vapors and gases, subjected the disturbed portion of the belt to an excessive upward tension, causing it to give way, at successive times, in a series of long parallel rents. By the sudden and explosive escape of the gaseous matter, the prodigious pressure, previously exerted on the surface of the fluid within, being instantly withdrawn, this would rise along the whole line of fissure in the manner of an enormous billow, and suddenly lift with it the overlying flexible crust. Gravity, now operating on the disturbed lava mass, would engender a violent undulation of its whole contiguous surface, so that wave would succeed wave in regular and parallel order, flattening and expanding as they advanced, and imparting a corresponding billowy motion to the overlying strata. Simultaneously with each epoch of oscillation, while the whole crust was thus thrown into parallel flexures, we suppose the undulating tract to have been shoved bodily forward, and secured in its new position by the permanent intrusion, into the rent and dislocated region behind, of the liquid matter injected by the same forces that gave origin to the waves. This forward thrust, operating upon the flexures formed by the waves, would steepen the advanced side of each wave, precisely as the wind, acting on the billows of the ocean, forces forward their crests, and imparts a steeper slope to their leeward sides. A repetition of these forces, by augmenting the inclination on the front of every wave, would result, finally, in the folded structure, with inversion, in all the parts of the belt adjacent to the region of principal disturbance. Here, an increased amount of plication would be caused, not only by the superior violence of the forward horizontal force, but by the production in this district of many lesser groups of waves, interposed between the larger ones, and not endowed with sufficient momentum to reach the remoter sides of the belt. To this interpolation we attribute, in part, the crowded condition of the axes on the side of the undulated district, which borders the region where the rents and dykes occur, and to it we trace the far greater variety which there occurs in the size of the flexures.

In the progress of this bending and folding of the strata, throughout the undulated district, the continual introduction and consolidation in the fissured district, of fresh materials from the liquid mass beneath, rising in intrusive dykes, and filling the wide interstices of the broken strata, would permanently retain the inflected crust in the new attitudes into which it had been forced, and compensate for the reduction of horizontal breadth arising from the flexures. Permanent axes might even be produced without the fracturing of the crust being in all cases apparent at the surface, since innumerable fissures, of sufficient size to permit the sudden escape of an enormous quantity of elastic vapor, could temporarily form, and yet close again superficially, and still the strata be braced and retained in their flexured state by the dislodgement of fragments, and the intrusion and congelation of much lava matter in the lower parts of the rents.

This theory agrees strikingly with the singularly undisturbed condition of the strata, northwest of our great lines of fault. When describing, under a preceding head, some of these enormous dislocations, especially those of southwestern Virginia, an account was given of the gradual transition of structure, from the normal to the folded or inverted form, and thence, to a successive ingulfing of certain groups of strata, into a line of fault, presenting sometimes, for the distance of seventy miles, an actual inversion of the lower Appalachian limestone or slate, upon either the carboniferous limestone or the next inferior group. The commencement in all cases of these faults, in the steeply folded synclinal part of the flexure, immediately on the northwest of the finally inverted anticlinal curve, would seem to prove conclusively, that the fracture has been due to a profound folding in and inversion of the rocks, carried to the extent of producing an actual snapping asunder of the beds where most incurved, followed by a squeezing downward of the opposite side of the trough, by the horizontal northwestward thrust of the anticlinal portion, causing the lower strata of the latter to lie directly upon geologically higher groups. The enormous mass of rocky material, thus forcibly pressed down and firmly held there, would, we conceive, constitute a vast *subterranean barrier or dam*, capable of arresting, in some degree, the progress of the succeeding waves, and of protecting the region for a moderate distance, towards the northwest, or the leeward side of the fault, from the undulations to which it would otherwise have been exposed. In confirmation of this view, it may be stated, that in tracing a line of dislocation toward either extremity, while the extent of strata thrust down, as indicated by the amount of the hiatus at the fault, is inferred to grow progressively less and less, or, what is the same thing, the supposed subterranean dam, presumed to diminish in depth, the region behind it, on the northwest, becomes more and more undulated, until, when we pass beyond the extremity of the fault, to where the normal form of the flexure is restored, we find the strata to the northwest reared into bold anticlinal and synclinal curves. Such is remarkably the fact with the fault at the northwest base of the Peters's and East river mountain, in Virginia, as well as with that which lies parallel to, and southeast of, the Cumberland mountain; and, in a word, with all the faults and crushed axes of great length throughout Virginia, Pennsylvania, and Tennessee. Even where two such lines of dislocation occur, parallel to each other, at an interval of not more than eight or ten miles, the central parts of the intervening tract exhibit unusually little disturbance, notwithstanding their proximity to the lines of violent disruption on each side.

The assumed combination of the wave-like oscillation, and horizontal or tangential movement, will explain, we believe, all those general structural phenomena, which we have described as characterizing our Appalachian chain in all its length and breadth, and which obviously exist in many other mountain chains possessing numerous axes. It will account for all the varieties of flexure, normal, inverted, or dislocated, which are any where observable in the chain, since a mere difference in the ratio of the tangential to the undulatory movement, would produce every grade and form of inflection we have had to record.

The theory explains, moreover, the remarkable law of diminishing steepness in the flexures, as we cross the whole belt northwestward from the region of intrusive veins and dykes, which has evidently been the quarter of extensive and violent actual disruptions of the crust. It moreover affords a reason for the striking parallelism which prevails between the axes in every division of the chain, and the veins and dykes in the corresponding tracts to the southeast. In this rent and dislocated zone of country, beginning with the chain of the Blue ridge, the incalculably numerous and greatly extended dykes and veins that every where penetrate and fill the altered and hypogene rocks, comprise, we believe, an ample quantity of inwedged material, to balance the horizontal contraction of the whole plicated chain.

The mere fact of a regular gradation in the amount of flexure, is of itself a proof, that the axes thus related had a common source, while the direction of this gradation, clearly establishes, that the southeast was the quarter from whence the movement proceeded.

The views here entertained of the nature of the elevating action, afford a satisfactory cause for the arrangement of the axes in groups, since we have merely to imagine successive sets of pulsations of varying magnitude and momentum, to have followed each other in the same general period of disturbance, and we are supplied with a cause sufficient to produce all the diversity which we behold in the distances and directions of the flexures. The almost exact parallelism of these in each group, and the general parallelism of all that enter into the same division of the chain, are the necessary results of that wave-like movement in which we conceive the axes to have originated; and we confess ourselves at a loss to imagine how any other action, but an undulation of the crust, propagated in parallel lines, either straight or curving, could give rise to this extraordinary feature in these enormously extended anticlinal and synclinal lines.

The curious facts connected with the curving form of the axes, in certain districts, are likewise well accounted for by the hypothesis. Of those divisions where they are *convex to the northwest*, and where the curvature is generally so regular, we have merely to suppose that the disturbance began with the production of the axes of each adjoining division, that these terminated towards each other in an obtuse angle, but did not meet; and that, in the angle between them, there was afterwards formed another intermediate belt of undulations. The extremities of these last waves, encountering the flexures already formed in the adjoining straight belts, would be obstructed and retarded in their progress northwestward; but the middle portion of each billow, moving in a tract as yet free from permanent axes, would meet with less impediment, and advance with a higher velocity, so as to impart to the whole of each axis a curvelinear form. It appears, moreover, highly probable, that the fractures of the crust in the dislocated district in the southeast, would themselves be more or less curvilinear in the vicinity of previously formed rents approaching each other at an obtuse angle, and thus a tendency to that shape might be primarily impressed on all the undulations taking their origin in a region so circumstanced.

On the other hand, in those sections of the chain where the axes have a *concave curvature northwestward*, and where there usually exists less regularity in their sweep than in the convex groups, we may imagine that the lines of elevation of the two adjacent straight belts, terminating nearer and nearer to each other, as the axes receded towards the northwest, would soon mutually interfere, and the undulations originating at the southeast, in the space opposite the angle, would find their progress northwestward more and more impeded, as they advanced through the narrowing area between the ends of the flexures previously formed. By unequal and multiplied obstructions thus occasioned, the regularity of the axes in the intermediate division would be greatly impaired.

There is a curious arrangement in échellon, which we notice in many of the groups of axes of the Delaware river or New Jersey division, where, though individually nearly straight, they change their strike more and more to the north as we advance northeastward. This admits of a simple explanation, if we merely suppose a portion of the flexures in the next straight belt on the southwest to have been first produced, and these to have been followed by those on the northeast, which occupy New Jersey and the contiguous districts of New York, the undulations starting as usual from the southeast. The latter, originating last, with a more northern strike, would *converge* upon the former as the waves advance northwestward, and coming in contact with the eastern extremities of the previous flexures, would encounter a retardation at their southwestern ends, while their remote or northeastern extremities would be free to advance with their whole velocity. The natural tendency of this species of resistance, would be to *break* the retarded wave, and to give the northeastern portions a more northerly strike. The whole movement may be likened to the march of a platoon of soldiers in what is called a right oblique order, wherein the advanced files slightly wheel upon the left.

The hypothesis we have advanced, seems also to explain the important fact, that the whole undulated surface, estimated by the average change of level of any given stratum traced across the chain, rises in a regularly inclined plane southeastward, or towards the quarter where we find, by other evidence, that the uplifting and undulating action was most powerful. This circumstance, of a progressive rise of the whole belt towards the side which anciently lay near the shore of the Appalachian ocean, accords entirely with the belief, that under the now rent and dislocated margin of the chain, there was a vast accumulation of fluid rock, charged with compressed gaseous matter, which exerted on the crust an enormous disrupting tension.

On the Identity of the Undulations which produced the Axes, with the wave-like Motion of the Earth in Earthquakes.

That the undulatory movements which we suppose to have been the primary cause of our Appalachian axes, and generally of all other parallel flexures, were strictly analogous to well-known phenomena of the present day, is apparent, when we examine the nature of that tremendous agitation of the crust, which we call an earthquake. A *wave-like* undulation of the ground is of such common occurrence during great earthquakes, that we are inclined to consider it as their essential condition. On this subject, we possess the concurrent testimony of the best observers and historians of these events, particularly Michell, Dolomieu, Lyell, and Darwin. Michell, writing on the subject of "The Cause and Phenomena of Earthquakes," in the Philosophical Transactions for 1760, says, that the motion of the earth is partly tremulous, and partly propagated by waves, which succeed one another at larger and smaller distances, the undulation extending much further than the tremor. At Jamaica, in 1687–8, a gentleman saw the ground rise, like the sea, in a wave, as the earthquake passed along, and he could distinguish the effects for some miles, by the waving of the tree-tops on the hills. The same was witnessed in New England, November 18th, 1755. The wave-like motion of the great Lisbon earthquake, which happened on the first of November, 1755, was perceived by the motion of water, and the hanging branches in churches through all Germany, amongst the Alps, in Denmark, Sweden, Norway, and all over the British islands. This tremendous movement even reached the West Indies, a distance from the seat of principal violence, of nearly three thousand miles. A comparison of the times at which the first shock was felt at Lisbon and at other places, shows the undulation to have travelled at the rate of more than *twenty miles per minute*.

Dolomieu, in his dissertation on the great Calabrian earthquake, states, according to Mr. Lyell, that "the surface of the country often heaved like the billows of a swelling sea, which produced a swimming in the head like sea-sickness," and he further mentions as "a well-known fact, that the trees sometimes bent during the shocks to the earth, and touched it with their tops."* This rocking motion of the surface was likewise experienced by Darwin, in South America, who states, on the authority of Acasto, that the earthquakes of that country extend three hundred, six hundred, nine hundred, and some of them even one thousand five hundred miles along the coast.†

That this motion is of the nature of an actual billowy oscillation of the crust, is likewise plainly indicated by the attendant

* See Lyell's Principles, Boston edition, vol. 2. p. 330.

† See a paper by Darwin, in Transactions of Geological Society of London

phenomena, especially by the uniformity in the direction which the earthquake takes, and by the opening of great chasms and fissures in the ground, parallel to each other, and perpendicular to the course of the shock or undulation. Thus it is recorded, that, during the earthquake that shook the valley of the Mississippi, in 1811, the inhabitants felt the earth rise in great undulations, and that the ground opened in numerous parallel fissures, having a direction from northeast to southwest. This close correspondence between the direction of the cracks, and that which invariably characterizes our Appalachian axes or faults, is a remarkable circumstance, that well demands the attention of geologists. It lends a further probability to our hypothesis, which merely imagines a very much more energetic series of undulations to have occurred during the elevation of all this part of the continent. There is reason to think that this agreement in the direction of the forces at periods so remote, is not merely casual; for it appears, from a statement of Michell, that of five considerable earthquakes, felt in New England before his time, three are known to have come from the northwest, and the other two are supposed to have had the same direction. Recent observations in Scotland indicate that the earthquake which was there felt in October, 1839, consisted of undulations moving from northwest to southeast, or in a direction perpendicular to the strike of all the older axes of that country.

Of the manner in which the wave-like movements in earthquakes may be supposed to originate, Michell suggests, that large tracts of country may rest on fluid lava, which, when disturbed, may transmit its motion through the overlying crust; but he offers the following as the explanation of the mode in which the undulations may take place. " Suppose a large cloth, or a carpet, spread upon a floor, to be raised at one edge, and then suddenly brought down again to the floor; the air under it being by this means propelled, will pass along, till it escapes at the opposite side, raising the cloth in a wave all the way as it goes. In like manner, a large quantity of vapor may be conceived to raise the earth in a wave, as it passes along between the strata, which it may easily separate in a horizontal direction, there being little or no cohesion between one stratum and another. The part of the earth that is first raised, being bent from its natural form, will endeavor to restore itself by its elasticity, and the parts next to it being to have their weight supported by the vapor which will insinuate itself under them, will be raised in their turn, till it either finds some vent, or is again condensed by the cold into water, and by that means prevented from proceeding any further."*

Now we conceive that there is a simpler view of the origin of the undulation, and one which is more in accordance with sound dynamical considerations, and with all the recorded observations upon earthquakes. In place of supposing it possible for a body of vapor or gaseous matter to pass horizontally between the strata, or even between the crust and the fluid lava upon which it floats, and with which it must be closely entangled, we are inclined to attribute the movement to an *actual pulsation*, engendered in the *molten matter itself*, by a linear disruption under enormous tension, giving vent, explosively, to elastic vapors, escaping either to the surface, or into cavernous spaces beneath. According to this supposition, the movement of the subterranean vapors would be *towards*, and not from the disrupted belt, and the oscillation of the crust would originate in the tremendous and sudden disturbance of the previous pressure on the surface of the lava mass below, brought about by the instantaneous and violent rending of the overlying strata.

It has been denied by some — and the objection seems to be acceded to by Mr. Lyell — that the so-called wave-like motion of the surface in earthquakes, has "any strict analogy with the undulations of a fluid." On the other hand, "it has been suggested, that a vibratory jar may be produced at a considerable depth, by a sudden fracture of the solid crust, and that the vibrations may be propagated upward through a mass of rock, even several miles thick. The first vibration which reaches the surface will lift the soil, and then allow it to sink again; immediately after which another, which may have radiated from the same deep-seated point, may arrive at a contiguous spot on the surface, and cause

* Michell, Phil. Transactions, 1760.

a similar rise and fall, and so others in succession, giving rise to a progressive motion of the ground, very similar in appearance to a wave of the sea."*

To the suggestion of a propagated vibrating jar being the cause of the rocking of the surface, we will reply by simply referring to all the authentic accounts of earthquakes, in which the regularly progressive march of the billowy undulation is so frequently described by eye-witnesses, and likewise to the statements of Michell, who gives, from abundant data, the *very rate* of the passage of the great Lisbon earthquake, across an area exceeding three thousand miles in breadth. As regards the other supposed difficulty, that the radius of each superficial curvature must be very small, we contend that this is by no means a necessary inference from the phenomena, since if we take into consideration the prodigiously high velocity with which earthquakes seem to move, we find a reason at once, why tall objects, like trees, may rock from side to side with a rapid oscillation, while the wave which disturbs them may possess an enormous breadth. A low and broad wave, if moving slowly, would only tilt the objects under which it might pass, into attitudes perpendicular to its gentle slopes, but the lowest and broadest billow, passing with the amazing speed of the Lisbon earthquake, might, by suddenly shoving the foundations or pedestals of objects from beneath them, and as suddenly pushing them in the opposite direction, cause them to swing rapidly through arcs of almost any extent.

While the evidence, therefore, seems ample, of the existence of a wave-like motion of the earth's surface during earthquakes, facts are not wanting which indicate the recent production, from this cause, of permanent anticlinal axes. Thus we find, in Darwin's Journal of Travels in South America, the following interesting statement. Mr. Gill, an engineer, mentioned to that intelligent traveller, that following up the bed of a stream, strewed with sand and gravel, and showing in one place, a channel in the solid rock about forty yards wide, and eight feet deep, he found himself suddenly going *down* hill, the whole descent amounting to forty

* Lyell's Principles, Boston edition, vol. 11.

or fifty feet of change of level. Here there was a decided arching of the surface, by which the river had been displaced from its ancient valley. Occurring in Chili, in a country so frequently visited by earthquakes, there can be little doubt as to the origin of this local anticlinal flexure in the earth's crust.

We are inclined to regard the Ullah Bund as another example of an anticlinal axis formed in modern times by an earthquake. According to the description and map furnished by Mr. Lyell, in his admirable account of earthquakes contained in his Principles, this is a long elevated mound, extending from east to west across the eastern arm of the Indus, near the fort and village of Sindree. It is upwards of *fifty miles in length*, and runs parallel to a line of *subsidence*, along which the previously low and perfectly level plain around Sindree became permanently flooded. It is conjectured to be, in some parts, sixteen miles in width, and to have a height above the original level of the delta, of ten feet, which it seems to preserve very uniformly.

Of the Date of the Appalachian Axes.

It has been stated already, that, excepting in one or two localities, the Appalachian formations constitute an unbroken succession of conforming strata, from the lowest members of the system, which repose immediately on the primary or metamorphic rocks, to the highest of the carboniferous strata. We must therefore conclude, that the elevatory actions, which lifted the entire chain above the level of the ancient sea, and impressed upon it those symmetrical features of structure which we have described, could not have begun, at least with any degree of intensity, until the completion of the carboniferous formation. That the principal movement *immediately* succeeded the termination of this period of gradual operations, or more properly arrested the further progress of the coal-formation, is, we think, clearly proved, by the fact, that nowhere do we meet with any strata, referable to the next succeeding or new red sandstone period, overlying the highest rocks appertaining to the coal; and it can scarcely be supposed, that throughout so vast an area, embracing several enormous basins, in which the upper carboniferous rocks have been preserved, all traces of that newer group, if deposited, should have been so entirely swept away, as not to have left its fragments even in any part of the wide tracts over which the coal-rocks are spread. An additional reason for believing that the elevation and flexure of the strata did not take place as late as the era of the new red sandstone, is to be found in the remarkably undisturbed manner in which a set of rocks of the age, approximately at least, of the European new red group, rest unconformably on the axes which traverse the Appalachian formations. All the geological relations of these overlying rocks, occupying a very prolonged belt to the southeast of all the carboniferous strata, but especially those of their organic remains, would seem to ally them closely to the New red sandstone group of Europe, and probably to its newest division. Extending almost continuously in a narrow belt from the valley of the Connecticut, to beyond the southern boundary of Virginia, these strata neither contain any axes of elevation, nor do they exhibit even a conformity of strike with the neighboring Appalachian and metamorphic rocks; and, although they repose, throughout a great part of the belt, immediately on the folded and inverted older strata, they furnish not the slightest indication of having been disturbed by the movements which produced the numerous axes beneath. We may hence confidently infer, that the great undulations which elevated those older formations, from the metamorphic to the carboniferous rocks inclusively, were antecedent to the deposition of these newer beds, and therefore that the age of the axes has been correctly determined to be antecedent to the commencement of the new red sandstone period.

That few or none of the principal Appalachian axes originated before the last of the coal strata were deposited, is demonstrably proved by the almost universal conformity or parallelism of all the strata. It is only necessary to consult the several sections appended to this paper, to recognize the important fact, that from the earliest to the latest of these Palæozoic rocks, extending probably somewhat further back than the Silurian formations of Europe,* and terminating with the last layers of the coal, no per-

* See a paper by Conrad, in Journal Academy of Natural Science, vol. 8, part 21.

manent flexures or other disturbances of the crust occurred, to interrupt this continuous and amazingly prolonged succession of parallel deposits.

In thus confining the era of the principal movement which elevated the Appalachian chain to a comparatively short period, at the very close of the carboniferous formation, we are far from implying that a few local elevations, and many minor oscillations of the surface, unattended by permanent flexures, did not occur previously to this final, and, beyond all comparison, most energetic effort of the subterranean forces. The unconformable superposition locally, of the Helderberg strata, upon the Hudson river slates, in the vicinity of the town of Hudson, is a sufficient evidence that even at an early period in the history of the Appalachian formations, this part of the region was disturbed by a *considerable movement* of the strata already deposited; and there are indications that similar agitations of the Appalachian territory, but to a much feebler extent, were experienced at the same and at other periods, during the progress of these formations. But, with the single local exception spoken of, none of these disturbances appear to have interrupted, however partially, the perfect general conformity of the strata throughout the whole Appalachian system. The occurrence of *feeble* movements, from time to time, in the earlier ages of the long Appalachian period, is clearly proved by the presence of fragments of older strata, enclosed in the next succeeding beds, and also by the coarseness of the materials of which some of the formations largely consist. The phenomena of the coal-measures, at the same time, go to show, as one of us has attempted to argue in another paper, that these movements continued to increase in frequency and power, as the Appalachian period drew near its termination; the entire coal-formation being the result of alternate quiet accumulations, and sudden paroxysmal movements, terminating in that stupendous train of actions, which lifted the whole Appalachian chain from the bed of the ancient sea.

The obvious agreement in point of date, between this, which was incomparably the most energetic and extensive change in the physical structure of North America, and the wide-spread revolution, which raised the European coal strata from the aqueous bed in which they were deposited, is a result of the highest interest in the comparative geology of the two continents. It would seem that the movement which produced so general and sudden a cessation to the progress of the coal strata, led to grander changes in the earth's surface than any disturbance since. Those displacements of land and sea, which severally terminated the Silurian and Devonian systems in Northern Europe, great as they truly appear, were, after all, but *local* events; not extending, except in their indirect consequences, to the distant Appalachian shores, and, it would seem, hardly to the oceanic tracts of the European basin in Russia. Over *how wide* a limit these movements were decidedly influential in the *organic* world, must soon become a problem of the highest interest to our science.

Analogous Phenomena of Axes in other Countries.

A perception of the important and novel bearings of the curious laws of structure here described, upon many points in geological dynamics, has led us to examine, with deep interest, the valuable and accurate labors of Fitton, Martin, De la Beche, Dumont, Murchison, Sedgewick, Weaver, Hopkins, and other eminent European geologists, in the expectation of finding in the phenomena they describe, evidences of analogous laws.

While studying, with this view, such memoirs, sections, and maps as were within our reach, we have enjoyed no small gratification in discovering, what we consider numerous striking proofs of the prevalence of similar structural features in some of the most interesting geological regions in Great Britain and on the continent.

Among these we would first mention the peculiarly interesting districts of Wales, to which the admirable researches of Messrs. Sedgewick and Murchison have, of late years, imparted so high a geological importance. In the beautiful and elaborate work of the latter geologist, the publication of which forms one of the great eras in geological science, we think we discern very distinct proofs that the Cambrian and Silurian axes of Wales, possess similar structural features with those of our Appalachian chain. While the older strata of the Berwyn mountains, as described by Mr. Murchison (Silurian System), would seem, by their altered character, and frequently inverted dips, to mark a close proximity to one of the great lines of disturbance of the district, that lying towards the northwest, from which has been propagated a combined uplifting and tangential force; the contour of the undulations, lying more towards the southeast, when unaffected by faults or local disrupting action, exhibits a general conformity to our law of a steepening flexure, on the side towards which the movement has proceeded. As illustrations of this law, we would beg to refer the reader to a few of the beautiful sections appended to Mr. Murchison's work on the Silurian System.

First. Plate 31, fig. 5. Section across the Ludlow and Brecon anticlinal, exposing the valley of elevation of Wigmore lake.

Second. Plate 34, fig. 3. This exhibits, to the northwest, the lower Silurian *on end*, for some distance from its contact with the Cambrian, after which it passes by a bold sigmoid flexure, in which the southeast dips are *very steep*, beneath the upper Silurian.

Third. Plate 34, fig. 7. Shows, on the northwest, *inverted flexures or foldings*, in the Llandeilo flags, then steep southeast dipping Caradoc sandstone, and, following this, the Upper Silurian and the Old red, with gradually diminishing dips. Fig. 8, of the same plate, presents analogous phenomena, though they are less distinct.

Fourth. Plate 34, fig. 9. Displays an *inverted* and *folded flexure*, succeeded by steep southeast dips, in the flagstones of the Cambrian, following which are two *normal arches* in the lower Silurian.

To these Sections may be added the Vignette, page 359, presenting an axis in the Cambrian rocks of Caermarthenshire.

In the eastern portion of this district, bordering the Malvern hills, the flexures would appear to be related, according to the same law, to the great line of elevating action, extending in a north and south direction through that region. The *steeper* sides of the arches are now towards the *west*, and the lower rocks are often overturned, so as to dip towards the east, thus exhibiting a direction of flexure, nearly opposite to that of the strata near the Berwyn chain. As examples of these phenomena, we would refer to Plate 36, fig. 8, presenting a transverse section of the Malvern and Sedbury hills, and figs. 9, 9[b], 10, of the same plate, exhibiting the structure of the Woolhope axis.

The same general structural features, will, we confidently believe, be found to prevail in the perplexing stratification of those parts of Devonshire and Cornwall, which, of late years, have drawn out much earnest theoretical discussion among British geologists. An inspection of the sections accompanying Sir H. De la Beche's elaborate Report, those, for example, from Combemartin to Bolt-hill, and from Linton to Bideford, and a careful examination of the descriptions of this region, given by him in that work, and by Messrs. Sedgewick and Murchison, in their very able memoir " On the Physical Structure and older Deposits of Devonshire," induces us to venture the prediction, that, throughout the region to which they refer, the phenomena of folded axes will be found of very extensive occurrence, and that this folding and inversion, together with the general law of steepening flexure in a particular direction, will explain the frequent repetitions of certain groups of strata, and assist in removing much of the obscurity that still hangs round the intricate geology of some parts of that district.

Similar indications are, we think, presented in the structure of the southern and southeastern parts of Ireland, as described by Weaver, Griffith, Hamilton, and Austin. Among these may be instanced *the great predominance of southern dips*, those to the north being only occasional and of short continuance; a result, in our view, naturally arising from a succession of folded and steeply normal flexures, due to a pulsatory movement propagated from the south. The evidences of such foldings and inversions, are, we think, quite observable, in the account given by Mr. Weaver, of the parallel bands and patches, in échellon, of the older limestones, while the steepened dip, and extensive folding and inversion among the higher rocks, resulting from the same forces, are strongly implied in the section given by the same author, through the Dromagh coal-field.* Similar phenomena would seem to be referred to, also, by Mr. Austin, when, in speaking of the neighborhood of Waterford, he ascribes the numerous contortions of schistose rocks, considered by him as being of the age of the Silurian, to *excessive lateral pressure*.†

From the delineations and descriptions of the structure of the Alps, and more particularly of the Jura, which we have met with, we are led to believe that precisely similar structural features prevail in those disturbed chains. The various sections, illustrative of M. Thurman's work, 'Essai sur les Soulevemens Jurassiques,' may be appealed to as furnishing conclusive proof, that the axis-planes of the numerous parallel anticlinal and synclinal axes of the Jura, are in every case *oblique*, and that they dip, in a great majority of instances, south-southeast, or towards the Alps.

Belgium, and the Rhenish provinces, seem to exhibit features of structure strikingly analagous to those of our Appalachian chain; and we think we do not go too far, when we affirm, that in those "extraordinary derangements and disturbances," and those "almost incredible phenomena of dislocation, contortion, and inversion," referred to by Dr. Buckland, as having been so ably elucidated by M. Dumont, we clearly recognize some of the general laws described in this paper, and made familiar by our researches in the Appalachian belt. On this head we would refer to the observations of Messrs. Murchison and Sedgewick, contained in their memoir "On the Classification and Distribution of the Older Rocks of Germany," of which an abstract is published in the Proceedings of the Geological Society of London. These distinguished geologists, when speaking of the groups of strata beneath the lower Westphalian limestone, thus describe the structure of the region northwest of the chain of the Taunus. "For many miles south of the undisturbed range of the lower Westphalia limestone, the prevailing dip is about north-northwest; the country round Seigen is regarded as a kind of dome of elevation,

* See Memoir on the Geological Relations of the South of Ireland, by Thomas Weaver, Esq. Trans. Geol. Soc. Lond., 2d series, vol. V.

† See Proceedings of the Geol. Soc., Lond., No. 74.

composed of the lower part of this series; for, still further south, the dip is *reversed* to the south-southeast, and in a traverse from Seigen to the Taunus, across the strike, (a distance of about fifty miles,) the same dip is continued, with very few interruptions. Considering their high inclination, this fact seems to give an almost incredible thickness to the deposits in question. But the vertical sections do not give the order of superposition, for at Dillenburg, and on the Lahn, *two great Devonian troughs* are brought in among the older strata, *without any general change of dip;* and if we accepted the vertical sections as the sole proofs of superposition, we must place the Devonian, and a part of the carboniferous series, under the chain of the Taunus."

If we are correct in our interpretation of the phenomena here described, they present an instance of structure which is of frequent occurrence in the Appalachian belt, where the rocks of the southeastern portion of a synclinal flexure, are folded over into southeastern or inverted dips, or where the axis-planes of both anticlinal and synclinal flexures are inclined very obliquely to the horizon, dipping in parallel directions to the southeast. The chain of the Hundsruck, and its continuation, the Taunus, of which they regard the Quartzite and Chlorite slates as "but altered forms of a great Silurian group, under the Eifel limestone," would thus appear to occupy a similar position to that of some of the ridges on the southeastern margin of the Appalachian region, where we meet with very similar phenomena of alteration, accompanied by a large amount of intrusive matter, and adjacent to this, on the northwest, many inversions and foldings of the strata. Including, in one view, the portions of Belgium, the Rhenish provinces, the Westphalian coal-field, and the Hundsruck, Taunus, and Hartz ranges, described by those geologists as displaying an extended series of Cambrian, Silurian, and Devonian strata, we are strongly of opinion, that the relations of dip which they present, will be found reducible, in great part, to the laws of structure we have endeavored to develope, and fairly referable to a similar undulatory movement directed towards the northwest.

From the observations of Dr. Fitton, on the structure of the Wealden and associated formations, as detailed in his admirable memoir on the Strata below the Chalk, and likewise from the more recent investigations, in the same region, by Mr. Hopkins, of which a summary is to be seen in the proceedings of the Geological Society of London, for 1841, it would appear, that in the districts of the Wealden and Bas Boulonnais, the numerous axes observe a *curved* form, and are nevertheless *parallel* to one another. Mr. Hopkins, after describing several of these flexures, states, that "all these lines preserve a remarkable parallelism with each other, and with the curved central axis of the district." It would further appear, from the observations of these distinguished geologists, unless we have given an erroneous interpretation to their sections and descriptions, that a great number, if not all of these axes, present a much steeper dip on one side than on the other, and that this stronger inflection generally occurs on the same, to wit, the *northern side*. Speaking of the line from Farnham to Seven-oaks, Mr. Hopkins uses these words: "It is a line of flexure,* with a great dip to the north, but without the corresponding dip to the south, necessary to form an anticlinal arrangement, except in one or two localities. Towards the west, it runs immediately at the foot of the hogsback, with a dip, which, near its western extremity, amounts to seventy or eighty degrees." "Tracing it towards the east," he adds, that, "at some points the line assumes a distinct anticlinal character.

Dr. Fitton, in describing the interior of Kent (p. 134 and 135), gives several drawings of sections of this or an adjoining axis, in all of which the predominance of the dip on the northern side is distinctly marked. Alluding to one of these sections, he says: "Both sides of the saddle are visible within a few paces; the beds on the north rising at an angle of about sixty degrees, while on the south, they decline at an angle of forty-five degrees." As illustrating the same law, we would more particularly refer to the following colored sections, appended to Dr. Fitton's memoir.

* By the term flexure, as explained by the phrase, *one-sided saddles*, used in the same connection, we infer the author to mean, what we denominate, *oblique flexures*, while he restricts the term anticlinal, to those bendings which give, approximately, equal dips on the opposite sides.

First. The section across the Weald, from the South Downs, Western Sussex, to the Surrey hills. In this, the dip, on the northern side of the great axis, is represented as slightly greater than on the southern side.

Second. The two combined sections, along the southeastern and southwestern coasts of the Isle of Wight. The axis traversing this island, and continued to Purbeck, is represented on the map accompanying the memoir of Dr. F., as parallel with that of the Weald. The sections referred to cross this axis, and exhibit a much greater steepness of dip on the northern than the southern side.

Third. The three sections across the vale of Wardour, transverse to the axis of that region. In all of these, the preponderance of dip on the northern side is very great.

This series of curved or undulating axes, which are, in the main, parallel to each other, would thus appear to manifest laws of structure, strictly analogous to those of our Appalachian region; and they serve still further to confirm us in our belief of the prevalence of similar features, among the flexures, in all regions of extensive disturbance, as well as to increase our reliance on the justness of the theoretical views by which we have attempted to explain them.

In conclusion, we would express our belief, founded on the phenomena referred to in this memoir, and on numerous similar geological facts, of recent as well as ancient date, which cannot be mentioned in this place, that all great *paroxysmal actions*, from the earliest epochs, to the present time, have been accompanied by a *wave-like motion of the earth's crust.*

Observations of Subterranean Temperature in the Coal-Mines of Eastern Virginia. By Wm. B. Rogers, *Professor of Natural Philosophy in the University of Virginia.*

The important law of an augmenting temperature as we descend to considerable depths beneath the surface of the earth, has, it is well known, been amply demonstrated in regard to Europe, by the numerous observations made in the mines and artesian wells of that portion of the globe, but with the single exception of Humboldt's observations in Mexico, no direct recorded proof has yet been furnished of its applicability to the Continent of America. The results detailed in the present communication, forming the first published confirmation of this law as regards any part of the United States will, therefore, it is conceived, be viewed as an important contribution to our knowledge on the subject, and will, it is hoped, conduce to more extended observations of the same description in other parts of our country, where the requisite opportunities exist.

The mines in which these results have been obtained, lie in the most productive part of the Öolite coal-measures of Eastern Virginia, and are of various depths, from 100 to nearly 800 feet. These coal-bearing strata rest upon an irregular basin-shaped floor of sienitic and gneissoid rocks, which forms the lower limit of the workings, and is penetrated for a few feet by some of the deeper shafts, as well as by the shallow ones nearest the margin of the field. They consist in great part of felspathic and micaceous sandstone, the coarser beds of which, formed of the almost unworn materials of the neighboring crystalline rocks compactly reunited, are sometimes scarcely distinguishable from the weathered portions of the parent mass.

The coal, consisting of a single seam, or of two contiguous seams, having an aggregate thickness varying from twenty to fifty feet, lies within a few feet and sometimes a few inches of the undulating floor, separated from it by bituminous slates and shales. Beds of the latter material, abounding in impressions of plants, and in some localities with those of fish, rest directly upon the principal mass of coal, and occupy the interval between the seams, where there are two.

The most common dip is towards the west, often at a very high angle, but owing to original irregularities in the gneissoid floor, and enormous dislocations subsequent to the filling up of the basin, the strike and inclination of the beds are subject to sudden and great transitions.

The open texture, high inclination, and fractured condition of the strata, favoring the descent of streams from above, cause a large influx of water into many of the workings. This forming part of the liquid collected in the wells at the bottom of the principal shafts, prior to its removal by the buckets, imparts as I have always found, a lower temperature to the mass of water there accumulated than is proper to the bottom strata. The small streams flowing from between the surface of the granite and the coal, or from the rocks above the coal, have, on the contrary, always presented a close approximation to the temperature of the strata from which they make their escape. I have therefore, whenever practicable, resorted to such streams, occasionally comparing their temperature with that of the adjoining rocks, by a thermometer, duly inserted in the mass.

Some of the following observations, it will be seen, were made in workings in active operation, and where the heating effects of the workmen, mules, and lamps, might be supposed to have made the results too high. The amount of their influence, however, could not have been considerable, as the temperature was determined by plunging the thermometer into a body of water continually replenished from the rock. Indeed, as will be proved in the sequel, this influence upon the average result was more than compensated by the cooling effect of the drippings from above.

The remaining observations were made in shafts just completed or in progress, and where the chief modifying influence was the cooling agency of the drippings from the higher beds.

I. Observations made in Mines actually or but lately in operation.

1. *At Mill's and Reed's Mine*, called the Creekpit, the temperature was taken at three different levels, by plunging the thermometer for some time into the water collected at the bottom of the main shaft, and the shafts connecting the lower levels. The amount of water accumulated at these points was very considerable, and the liquid was continually drawn off by the engine and replenished from the galleries of the mines. The following were the results:

Depth.	Temperature.
318 feet,	59.° 5
375 "	61.
420 "	63.

2. *Greenhole Pit.* This is one of the comparatively shallow mines at the margin of the field. When the observation was taken there were but few hands employed in it. The temperature observed was that of a collection of water at the bottom of the shaft, about a foot in depth. Result:

Depth.	Temperature.
100 feet,	58.°

3. *Engine Pit belonging to the Black Heth Company.* The air of this mine was obviously a good deal heated when the workings were in active progress, and I therefore selected for my observations a gallery remote from any present operations, and in which no work had been done for some time. The thermometer was immersed in a pool of water about 18 inches deep continually supplied from the neighboring strata. It was afterwards inserted for some time into the rock of the floor, and with the same result, which was—

Depth.	Temperature.
412 feet,	63.°

The temperature of the water at the bottom of the main shaft of this mine was found to be 61.° 5; but in this case it was evident that a large amount of liquid flowed from the upper strata and thus reduced the temperature of the whole.

4. *Wills and Michael's Pit.* The works were in active progress in this mine when the observations were made. The temperature first noted was that of the water at the bottom of the main shaft; the second, that of a similar pool in the lowest level. The results were—

Depth.	Temperature.
386 feet,	62.°
570 "	65. 5

II. Observations made in Shafts either just completed or in progress.

1. *Black Heth New Shaft* (1836). This shaft, which was in progress at the time of my observation, had reached the depth of 380 feet. The water at the bottom, which collected rapidly, was derived in part from the small streams flowing in from the adjacent rock, and partly from that which dripped from the edges of the higher strata. The temperature of the liquid in a small pool was 60°. That of the rock, as shown by a thermometer inserted deeply into a crevice on one side, was 61.° 5. But the free access of moisture and air had no doubt depressed the temperature slightly, even in this position. Upon exposing the bulb to a stream of drops coming from some distance above, it indicated a temperature of 59°. It is therefore evident that the true temperature of the rock, at the bottom of this shaft, is somewhat over 61.° 5.

Depth.	Temperature.
380 feet,	61. °5

2. *Mid Lothian New Shaft* (1839). This shaft, cutting through a seam of coal 36 feet thick, penetrated a coarse grit for a few feet, and then struck into the sienitic floor. Immediately above and beneath the coal, and from the rock in contact

with the sienite, numerous small streams were flowing out into the shaft. In the lowest of these the thermometer was exposed until its temperature became stationary. The following was the accordant result of several such observations:

Depth.	Temperature.
780 feet, ...	68.° 75

3. *Mid Lothian New Shaft* (1842). This shaft, in the same field with the preceding, and near it, had at the time of my observations reached the depth of 600 feet. Near the bottom it passed through a thin seam of coal and coal shale, in all about six feet, and beneath this to the bottom, a distance of about ten feet, it exposed dark argillaceous slates, the main mass of coal not having then been attained.

At a point 330 feet below the top of the shaft, a beautiful and rather bold spring issues from the sandstone, which is conducted downwards by a gutter cut in a spiral form around the shaft. The temperature of this stream, where it first appears, was carefully measured, and found to be 61.° 75. At the bottom, numerous very small streams come in from the rock. These all agreed in giving the temperature 66.° 25, which I therefore infer to be very nearly the temperature of the strata at that depth. The very copious drippings from above, together with the spring before noticed, blending with the infiltration from the strata near the bottom, formed a considerable pool, requiring the active use of the buckets. The temperature of this mixed water I found to be 63.° 5.

At the time of these observations only two hands were at work in the shaft, and there had been no blasting for some time before I descended. I therefore consider the observations on the spring at 330 feet, and the small streams at the bottom, to be as accurate indications of the temperatures at those depths as this or perhaps any other method of examination admits of. We have therefore in this shaft—

Depth.	Temperature.
330 feet, ...	61.° 75
600 "	66.° 25

The former of these results, it will be seen, is slightly above the temperature of the Black Heth new shaft, previously cited, though this shaft was fifty feet deeper. This difference is doubtless owing to the very large amount of cooler water which descended in drippings to the bottom of the Black Heth shaft, causing a decided reduction of temperature in the rock, in which the thermometer was inserted.

Assuming 56.° 75, the mean temperature of Shockoe hill, Richmond, as a sufficiently near approximation to that of the region of these mines, which is only about twelve miles from the city, the following Tables will exhibit the results of my observations, together with the excess of the subterranean temperature, at each depth, over the average heat of the surface.

TABLE I. OBSERVATIONS IN MINES IN OPERATION AT THE TIME.

	Depth.	Temperature.	Excess.
Greenhole Pit,	100 feet,	58°	1.°25
Mills and Reed's Pit,	318 "	59. 5	2. 75
" " " "	375 "	61.	4. 25
" " " "	420 "	63.	6. 25
Black Heth Engine,	412 "	63	6. 25
Wills and Michael's,	386 "	62	5. 25
" " "	570 "	65. 5	8. 75

TABLE II. OBSERVATIONS IN SHAFTS EITHER JUST COMPLETED OR IN PROGRESS.

	Depth.	Temperature.	Excess.
Black Heth new shaft,	380 feet,	61.°5	4.°75
Mid Lothian (spring),	330 "	61. 75	5. 00
" " (bottom),	600 "	66. 25	9. 50
" " (deep),	780 "	68. 75	12. 00

Making no deduction for the depth of the *invariable* plane, the results embraced in the first table give, as the rate of increase of temperature with the depth, 1° for 74 feet.

Assuming sixty feet for the depth of this plane, a distance which, from the open and moist condition of the rocks, I think

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more likely to fall below than to exceed the truth, and calculating the ratio of increase beneath this point, I find it to be 1° for 62 feet.

Making like computations in reference to the second table, the results are—

1st. Estimated from the surface down, 1° to 66 feet.

2d. Estimated from the invariable plane down, 1° to 59 feet.

Comparing the numbers deduced from the two classes of observations together, it will be seen that the diminution of temperature in descending is *slower* in the *mines in active operation* than in the recently opened shafts; so that, whatever may be the extraneous heating influences affecting the former, they are more than counterbalanced by the permanent cooling due to the descent into all parts of the mine of the cooler water from above.

Comparing the three last observations in table second, the two former of which were made in the same shaft, and the last in one only a few hundred feet removed, there is ground for inferring that the rate at which the temperature increases grows less as the depth augments. In descending from 330 feet to 600, that is, through 270 feet, the rise of temperature is 4.°5; while in descending from 600 to 780, or through 280 feet, the rise is only 2.°5. This difference would, I think, have been less, could I have obtained the temperature at 780 feet free from the cooling influence of the copious drippings from above. Yet even with the most liberal allowance, there would still remain evidence of a diminishing rate of increase with the depth, such as has already been remarked by Mr. Fox and other European observers.

Considering the observations in the Mid Lothian shaft at 330 and 600 feet, as the ones most exempt from any known source of error, and deducing the rate of increase from them, I find the result to be almost precisely that inferred from table second, that is 1° for every 60 feet.

I may therefore, I think, in conclusion, affirm as approximately true, for the region in which these mines are situated, that from the *invariable plane* downwards for many hundred feet, *the temperature augments at the rate of* 1° *for every* 60 *feet of depth.*

EXPLANATION OF THE PLATES.

PLATE I.

FIGURES OF BACILLARIÆ: SECTION DESMIDIACEA.

Fig. 1. Desmidium Schwartzii, p. 117.
" 2, 3, 4, 5, 6, 7. Euastrum, different positions.
" 8. Euastrum margaritiferum, Ehr. a. b. different positions, p. 125.
" 9. Euastrum ———, a. b. two positions, p. 125.
" 10. Euastrum ———, p. 125.
" 11, 12. Euastrum ———, p. 126.
" 13. Euastrum ———, p. 125.
" 14. Euastrum ———, p. 126.
" 15. Xanthidium ———, p. 120.
" 16. a. b. Xanthidium ———, p. 120.
" 17. Arthrodesmus quadricaudatus, p. 121.
" 18. Arthrodesmus cutus, p. 121.
" 19. Micrasterias Tetras, p. 122.
" 20. Micrasterias Boryana, p. 122.
" 21. Micrasterias ———, p. 122.
" 22. Euastrum rota, Ehr. p. 123.
" 23. Euastrum crux-melitensis? Ehr. p. 123.
" 24. Euastrum, possibly a young E. rota, p. 124.
" 25. Euastrum ———, p. 124.
" 26, 27. a. b. Euastrum ———, c. d. smaller individuals, (Echinella oblonga of Greville?) p. 124.
" 28. Euastrum ———, p. 124.
" 29. Euastrum ———, p. 124.
" 30. Closterium lunula, p. 132.
" 31. Closterium moniliferum, p. 132.
" 32. Closterium trabecula? p. 132.
" 33. Closterium digitus? p. 133.
" 34. Closterium lineatum? p. 133.
" 35. Closterium striolatum, p. 133.
" 36. Closterium rostratum, p. 133.
" 37. Closterium tenue? p. 134.
" 38. Closterium ———, p. 134.
" 39. Scale, each division of which represents $\frac{10}{100}$ of a millimetre magnified equally with the sketches.

PLATE II.

Figures of Bacillariæ : Section Naviculacea.

Fig. 1. 1. a. Pyxidicula operculata, p. 135.
" 2. 2. a. b. Pyxidicula ——? p. 135.
" 3. Gaillonella moniliformis, p. 135.
" 4. 4. a. b. Gaillonella aurichalcea ; c. a globular joint, [p. 136.
" 5. Gaillonella distans, p. 137.
" 6. a. b. Gaillonella, varians, p. 137.
" 7. Gaillonella sulcata, a jointed cylinder, composed of several individuals ; b. base of a joint, p. 138.
" 8. Gaillonella ? p. 139.
" 9, 10. Actinocyclus ——, p. 140.
" 11. a. b. Actinocyclus, a. base ; b. side view, showing the alternate elevations and depressions which cause the light and dark portions seen on a. p. 140.
" 12. a. b. Coscinodiscus lineatus, p. 142.
" 13. a. b. Coscinodiscus patina, p. 143.
" 14. Coscinodiscus radiatus, p. 142.
" 15. Scale of $\frac{10}{100}$ millimetre, magnified equally with the sketches.
" 16. a. b. Navicula viridis, c. c. c. c. the orifices, p. 144.
" 17. a. b. Navicula viridis, copied from Ehrenberg, p. 144.
" 18. Navicula ——, p. 145.
" 19. Navicula ——, p. 145.
" 20. Navicula ——, p. 145.
" 21. a. b. Navicula striatula, p. 145.
" 22. Navicula ——, p. 146.
" 23. a. b. Navicula ——, p. 146.
" 24. a. b. Navicula sigma, p. 147.
" 25. a. b. Emersonia —— p. 147.
" 26. a. b. c. Eunotia arcus ; c. cross section, p. 147.
" 27. a. b. c. Eunotia —— ; c. cross section, p. 148.
" 28. Eunotia monodon, p. 148.
" 29. Eunotia diodon, p. 148.
" 30. Eunotia triodon.
" 31. Eunotia tetraodon, p. 148.
" 32. Eunotia pentodon, p. 148.
" 33. Eunotia serra, p. 148.
" 34. Cocconeis ——, p. 149.
" 35. Bacillaria paradoxa, p. 149.
" 36. a. b. Bacillaria ? tabellaris, p. 150.
" 37. a. b. Bacillaria tabellaris, full grown ? p. 150.
" 38. Bacillaria marina ? p. 150.
" 39. Tessela catena ? p. 151.
" 40. Fragillaria pectinalis, p. 151.
" 41. Fragillaria bipunctata ? p. 151.
" 42. a. b. Meridion vernale, p. 152.

PLATE III.

FIGURES OF BACILLARIÆ: SECTION ECHINELLEA.

Fig. 1. Synedra ———, a. fleshy base; b. fleshy projection at the summit, p. 154.
" 2. Synedra ———, a. b. different positions, p. 154.
" 3. Podosphenia? possibly Gomphonema, p. 155.
" 4. Gomphonema minutissimum, p. 155.
" 5. Gomphonema ———, p. 155.
" 6. Gomphonema acuminatum? p. 156.
" 7. Gomphonema ———, p. 156.
" 8. Echinella flabellata, p. 156.
" 9. Echinella ———, p. 156.
" 10. Cocconema ———, p. 157.
" 11. Cocconema ———, p. 157.
" 12. Achnanthes brevipes, p. 158.
" 13. Striatella arcuata, p. 158.
" 14. Naunema ———, p. 159.
" 15. Naunema ———, p. 160.
" 16. Naunema ———, p. 160.
" 17. Naunema ———, 17. a. single frustule, p. 160.
" 18. Spiculæ of Spongilla, p. 161.
" 19. Probably spiculæ of another species of Spongilla.
" 20. Amphidiscus rotula, p. 162.
" 21 to 23. Siliceous bodies of organic origin, found with fossil fresh-water Infusoria, p. 162.
" 24. Dictyocha fibula? Ehr. p. 162.
" 25. Fragment of the preceding, p. 162.
" 26. Dictyocha speculum, Ehr. p. 163.
" 27, 28. Siliceous bodies, found with the preceding, p. 163.
" 29. Binary, triangular, siliceous bodies found with the preceding, p. 163.
" 30 to 35. Siliceous spiculæ, &c. probably derived from marine sponges or Actinia, found with the preceding, p. 163.
" 36. Scale of $\frac{10}{100}$ millimetre, magnified equally with the drawings.

PLATE IV.

SECTIONS ILLUSTRATIVE OF MR. TAYLOR'S PAPER, TO SHOW THE PRACTICABILITY OF USING MINUTE VERTICAL SCALES IN GEOLOGICAL DEMONSTRATIONS, p. 93.

PLATE V.

FOSSIL SHELLS FROM THE SOUTHERN ATLANTIC STATES.

Fig. 1. Oliva litterata, Lam. p. 108.
" 2. Buccinum interruptum, Conr. p. 108.
" 3. Conus adversarius, Conr. p. 108.

Fig. 4. Cerithium unilineatum, Conr. p. 108.
" 5. Mitra Carolinensis, Conr. p. 109.
" 6. Cypræa Carolinensis, Conr. p. 109.
" 7. Fasciolaria mutabilis, Conr. p. 109.
" 8. Dispotæa multilineata, Conr. p. 109.
" 9. Dispotæa dumosa, Conr. p. 109.
" 10. Cassis Hodgii, Conr. p. 109.
" 11. Mactra crassidens, Conr. p. 110.
" 12. Mactra subparilis, Conr. p. 110.
" 13. Cardium sublineatum, Conr. p. 110.
" 14. Gnathodon minor, Conr. p. 110.
" 15. Amphidesma constricta, Conr. p. 110.
" 16. Cardita perplana, Conr. p. 111.
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PLATE VI.

Isotelus megistos, Locke, p. 221.

PLATE VII.

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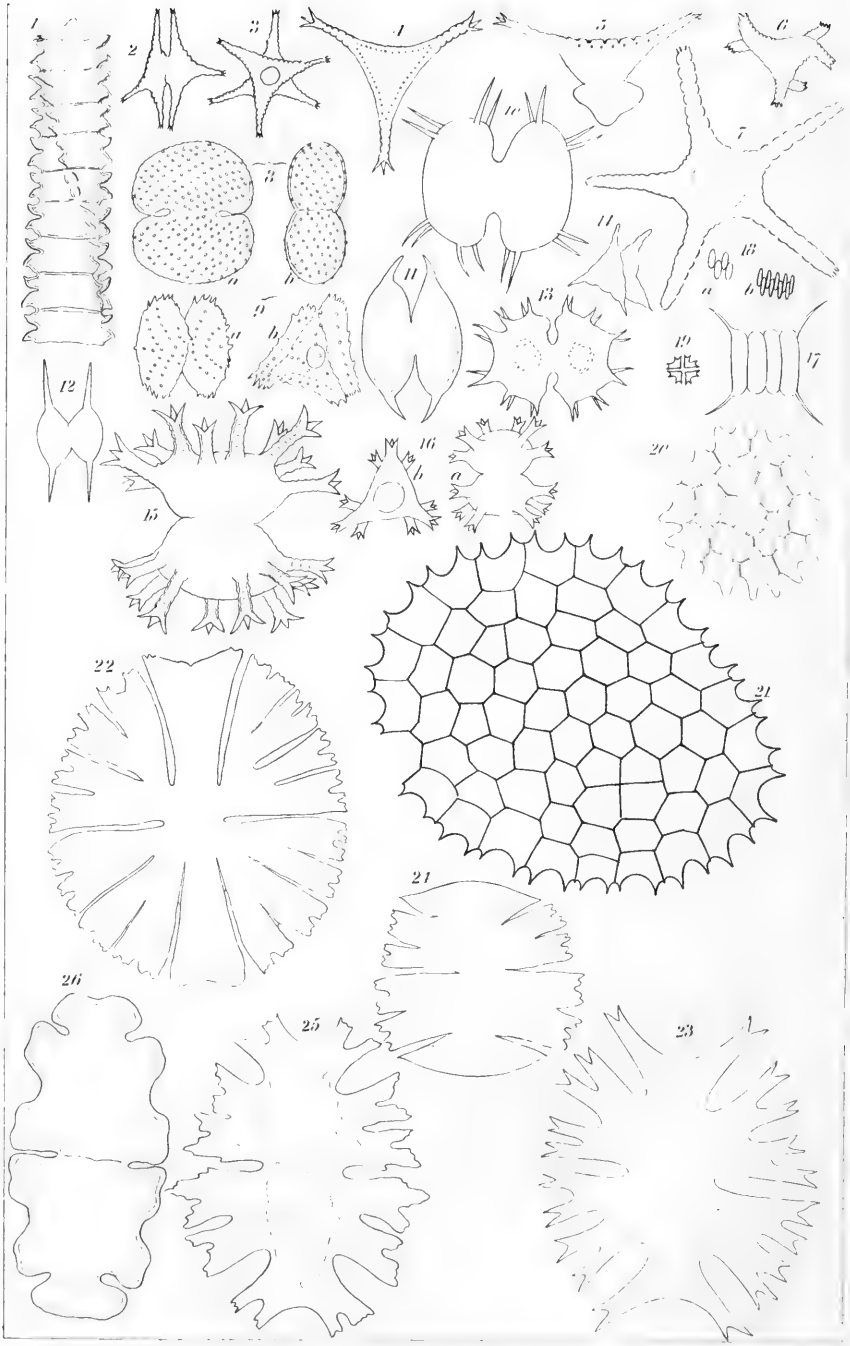

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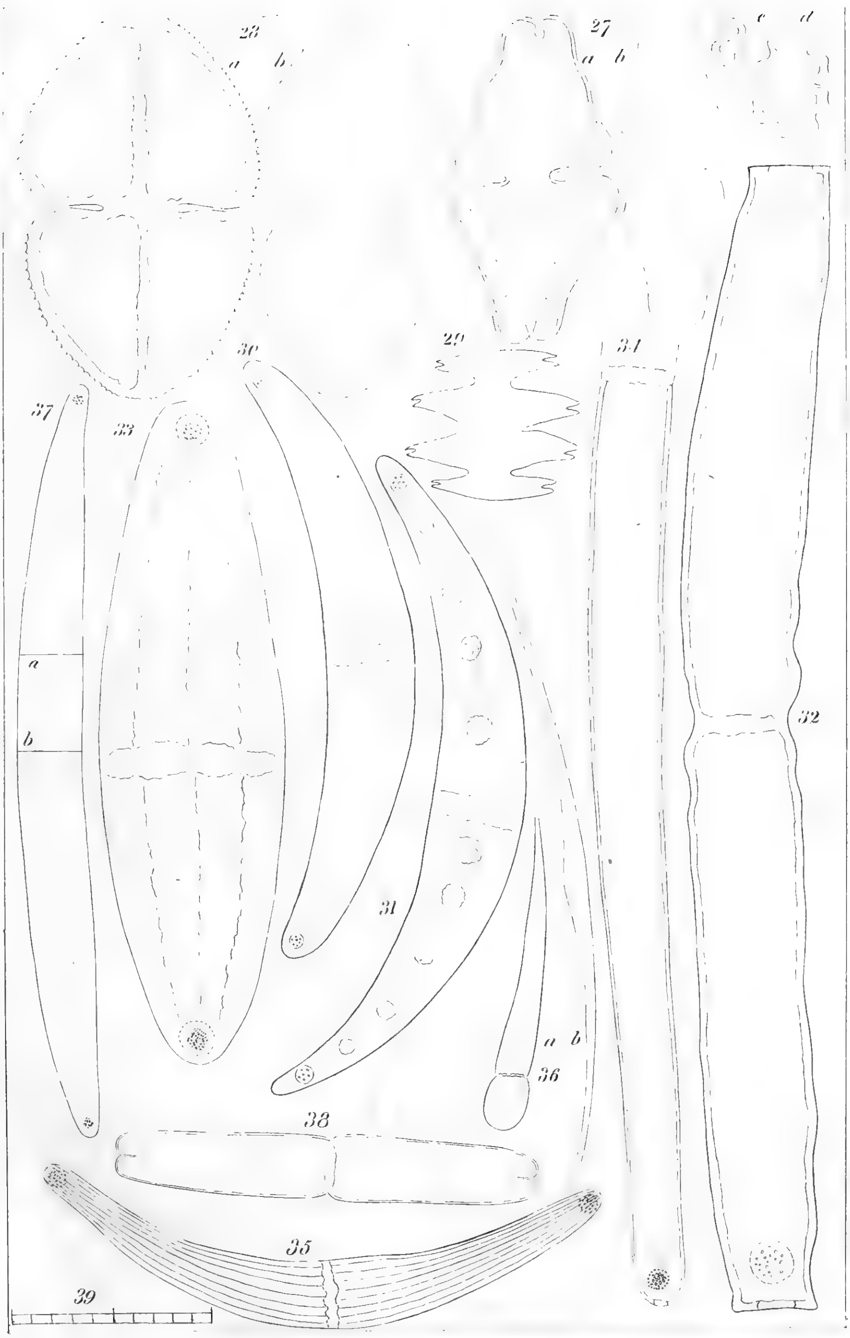
ILLUSTRATIONS TO PROF. J.W. BAILEY'S



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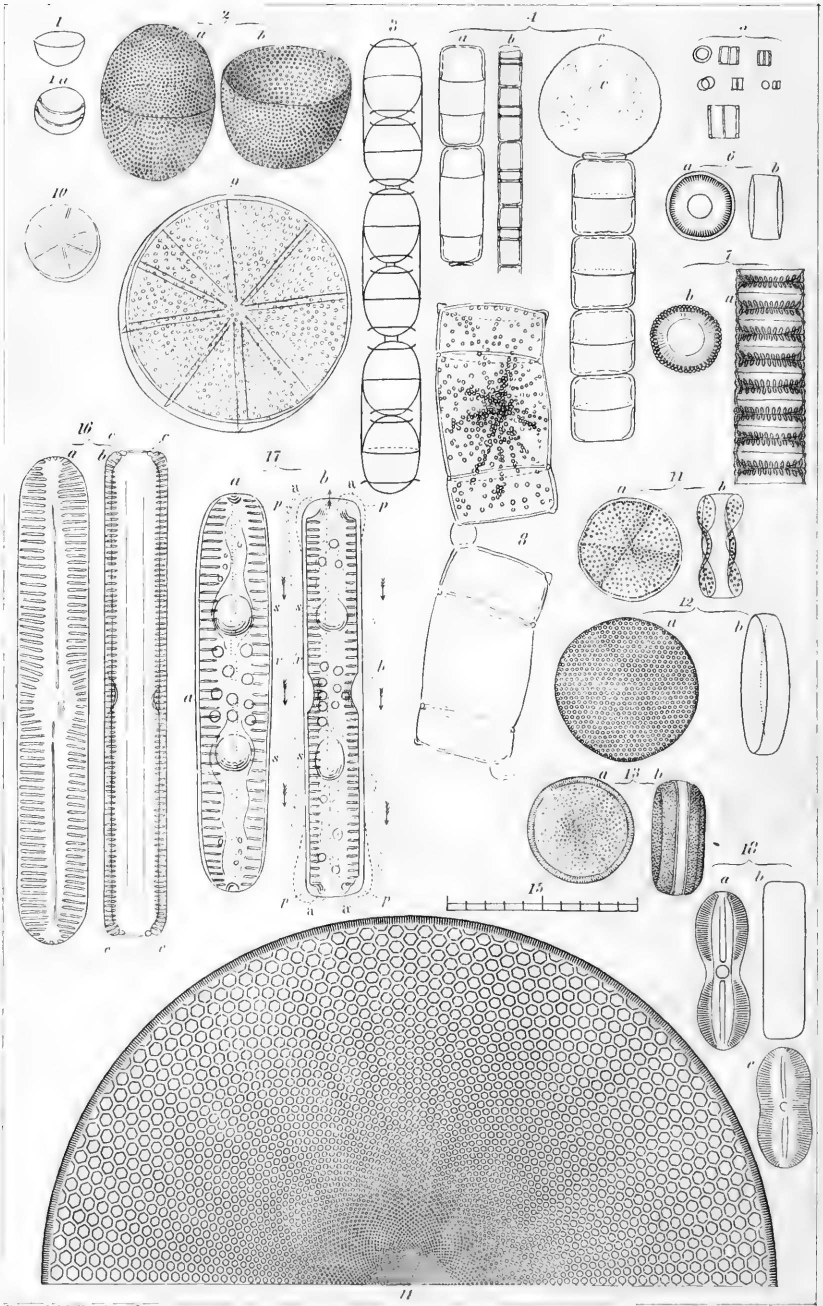
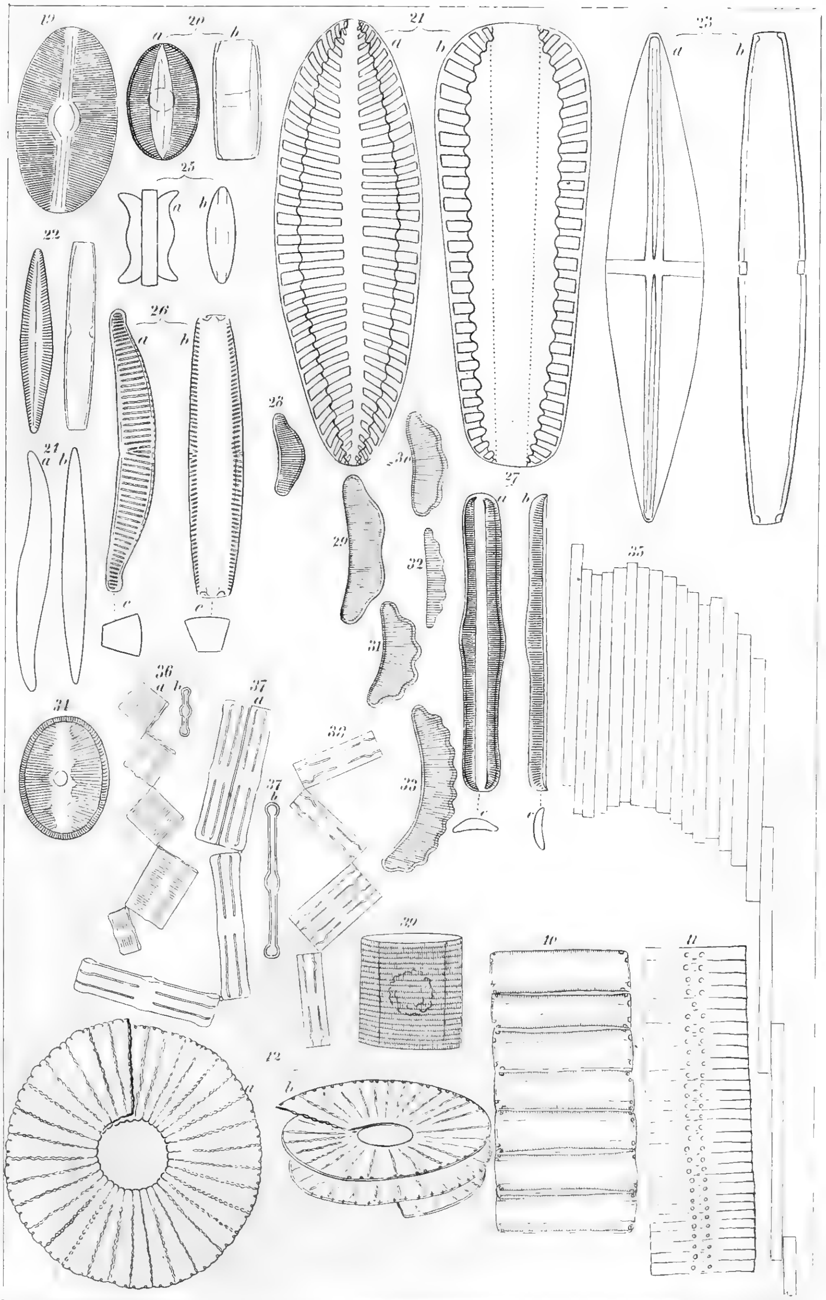


Prof. J.W. Bailey Del. Daggett, Hinman & Co. Sc.

Plate Second, Part Second; the Naviculaceæ.

ILLUSTRATIONS TO PROF. J.W. BAILEY'S



Prof. J.W. Bailey Del. *Duggett, Hinman & Co. Sc.*

Plate Second. Part Second. the Naviculaceæ.

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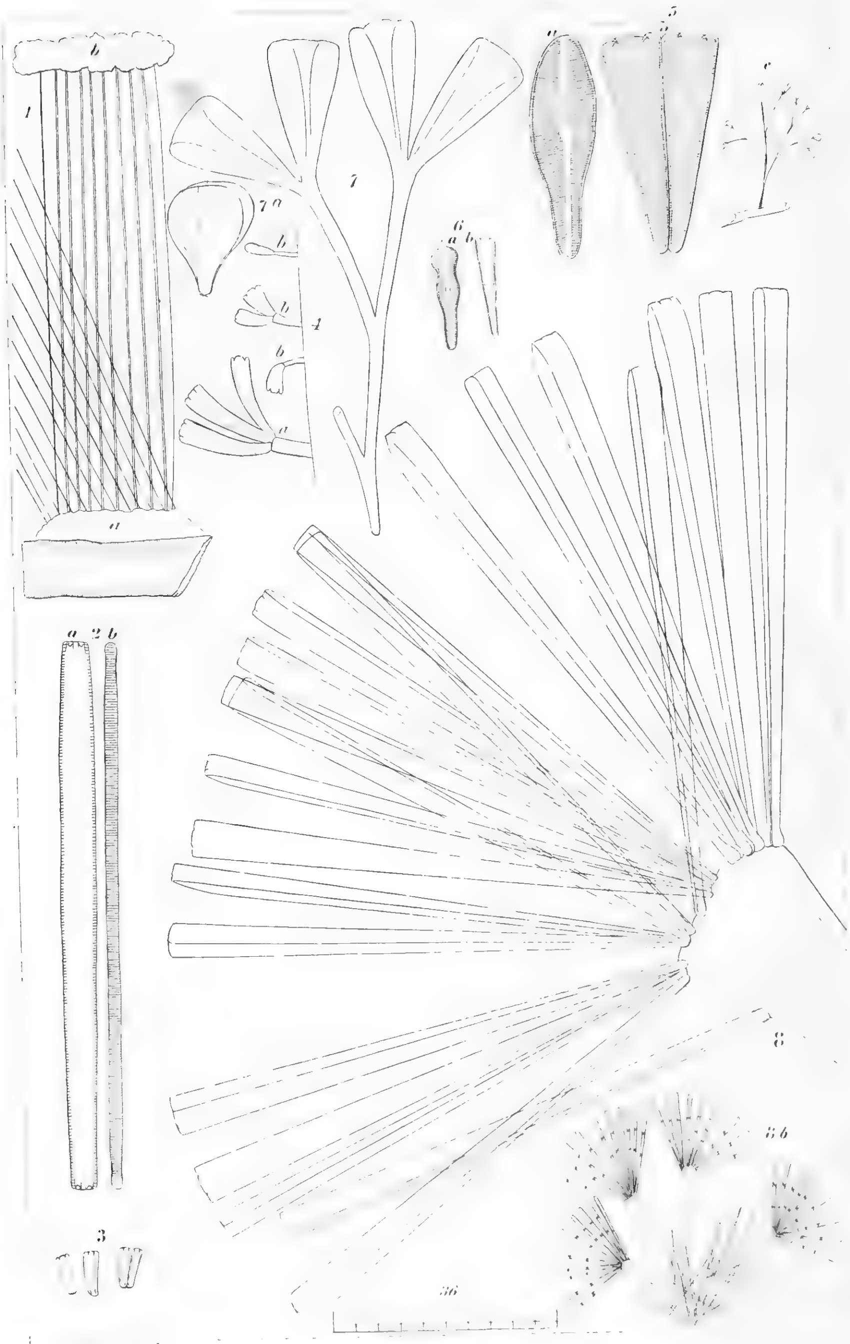

Prof. J.W. Bailey del.

Plate Third, Part Third.

ILLUSTRATIONS to PROF. J.W. BAILEY'S

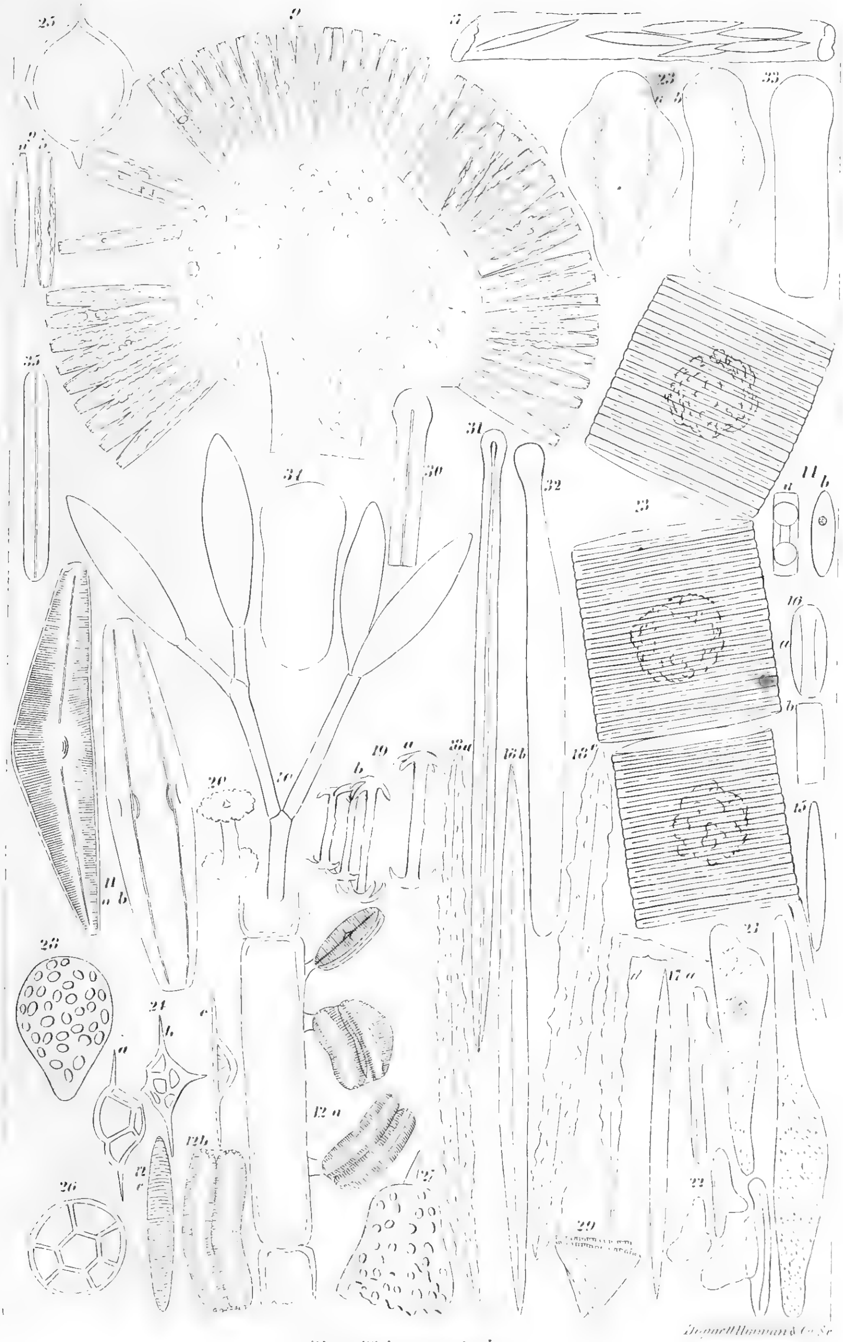

Plate Third, Part Third

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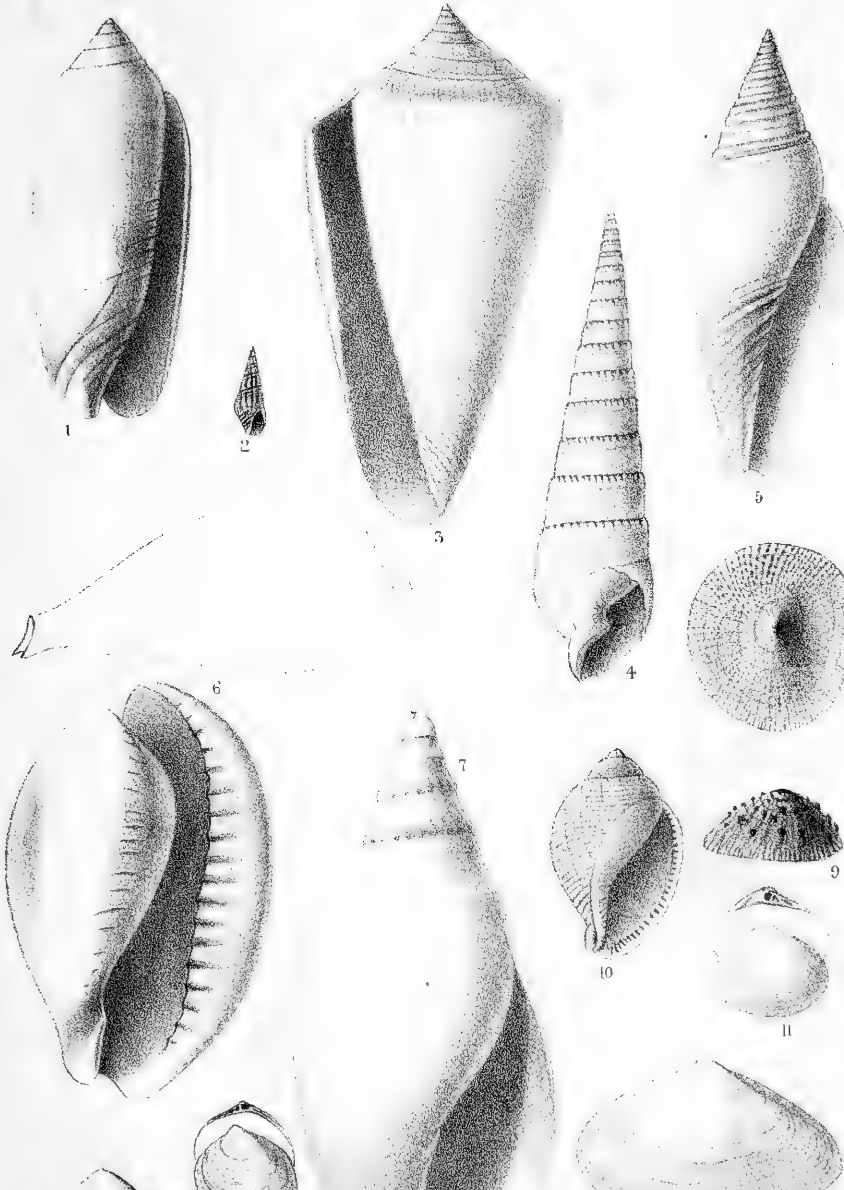
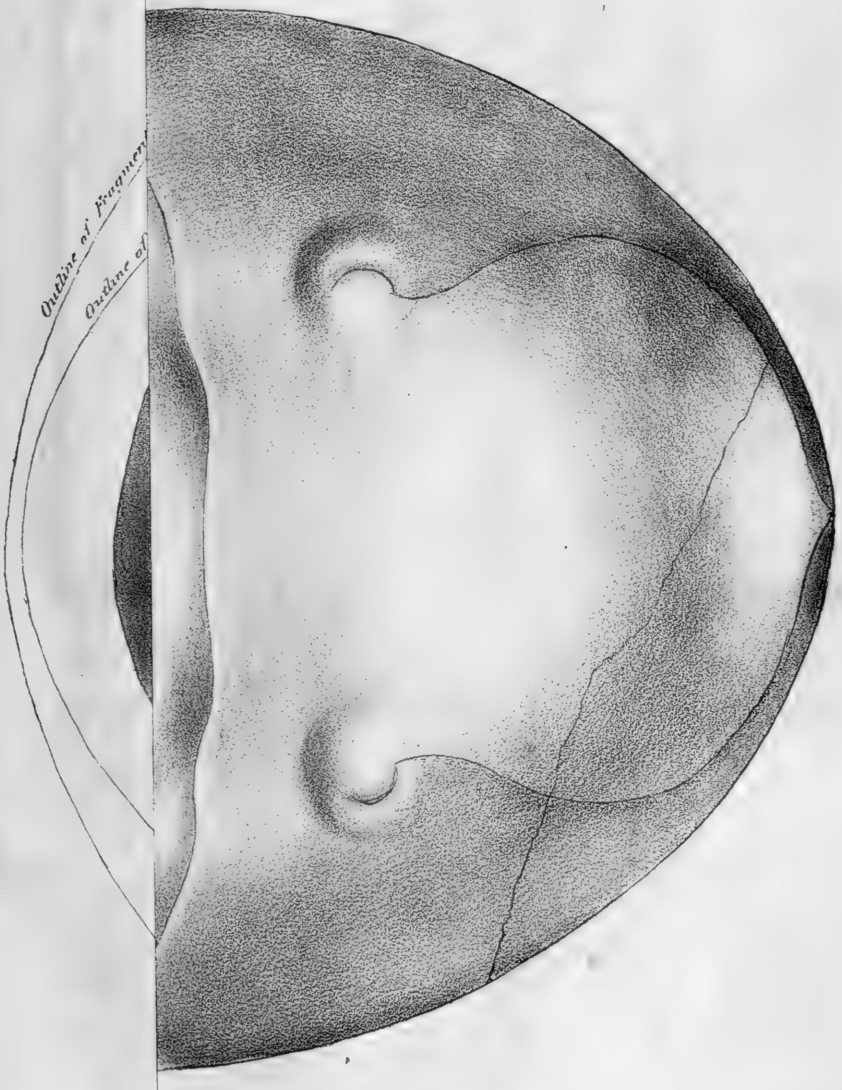
Pl.V



T. A. Conrad del. on stone.

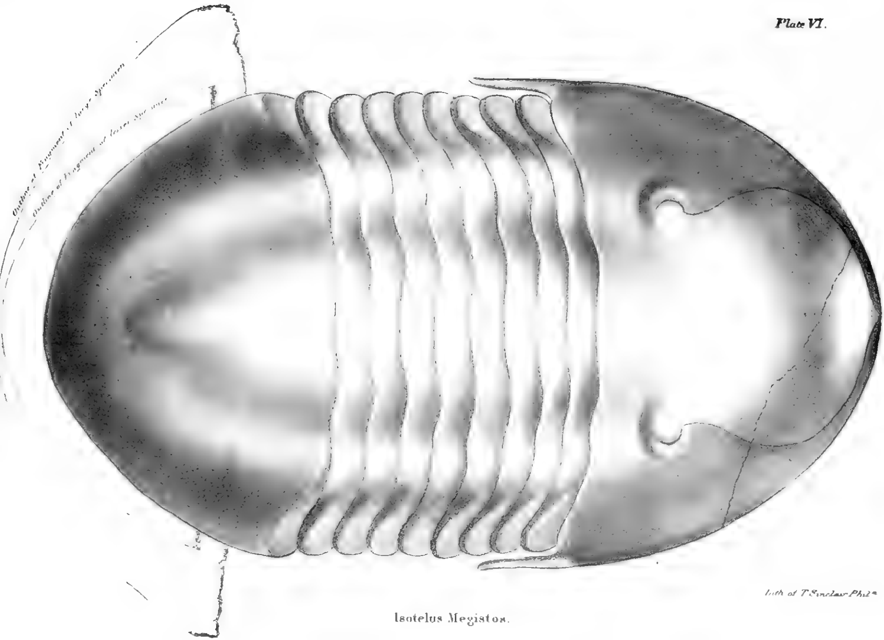
Lith. of T. Sinclair, Phil^a.

Plate VI.



Lith. of T. Sinclair Phil.a

Plate VI.



Lith of T. Sinclair Phil^a

Isotelus Megistos.

Plate VII.

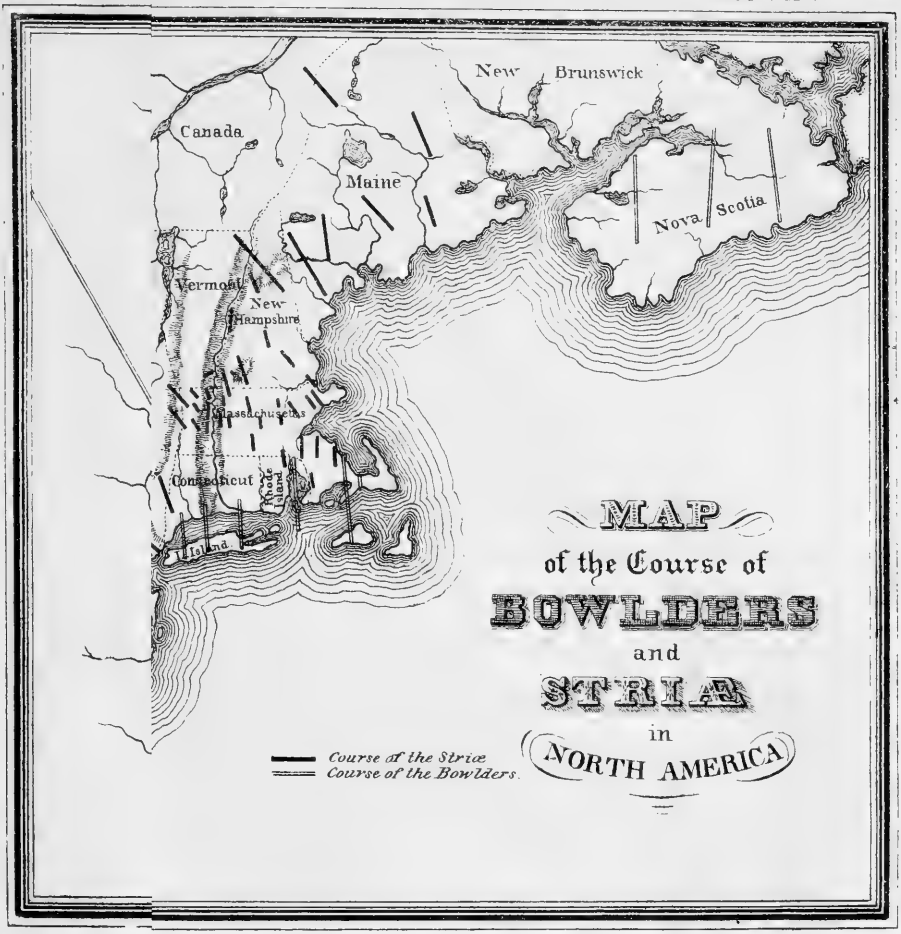
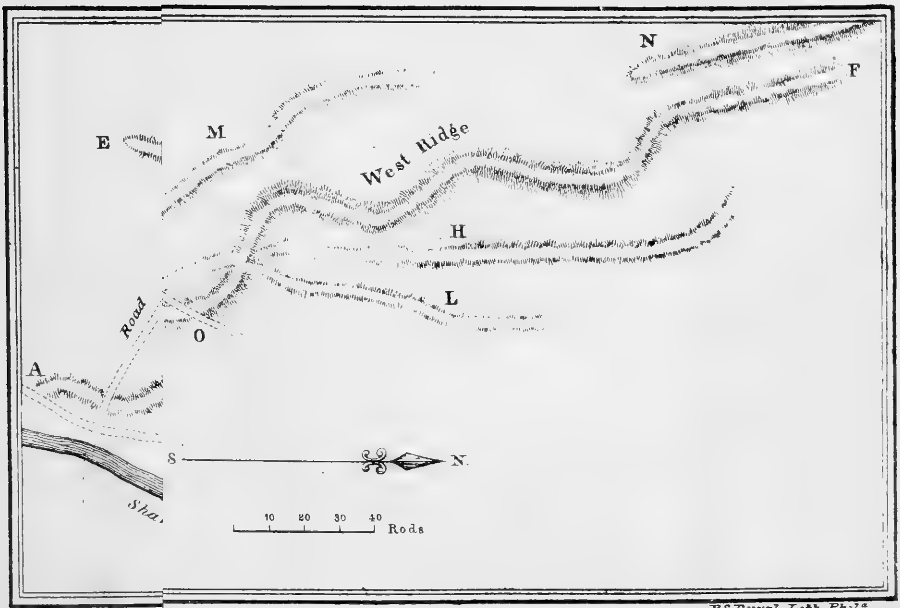


Plate IX.



On Stone by G. Schuma[...]

P.S. Duval, Lith. Phil[a]

Plate VII.

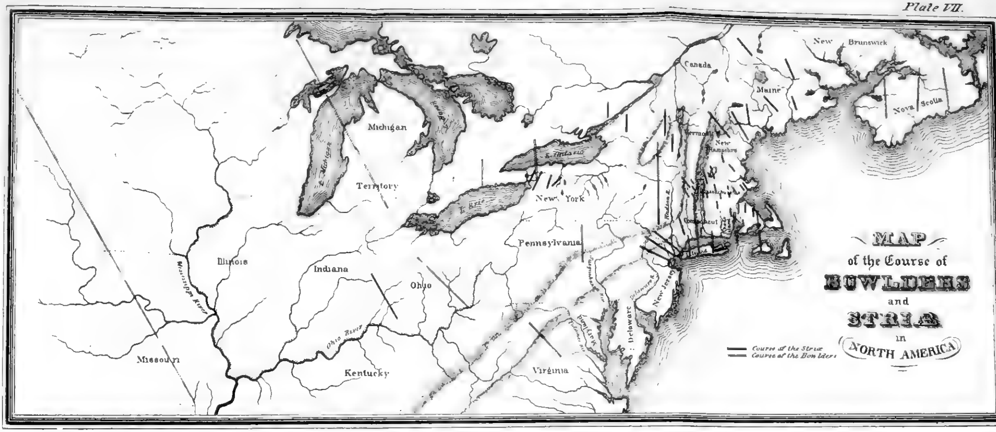


Plate IX

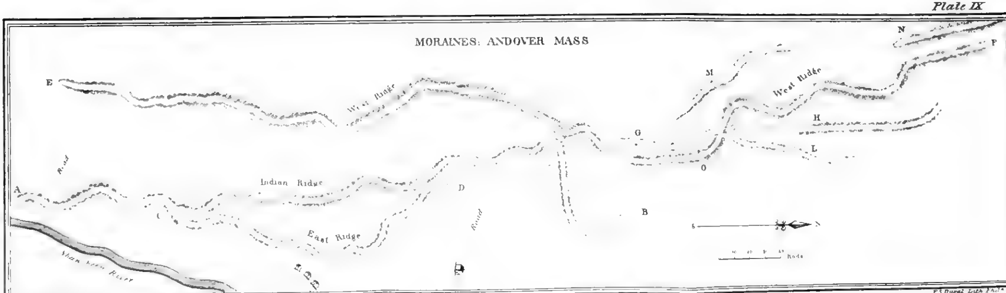


Fig. 4.

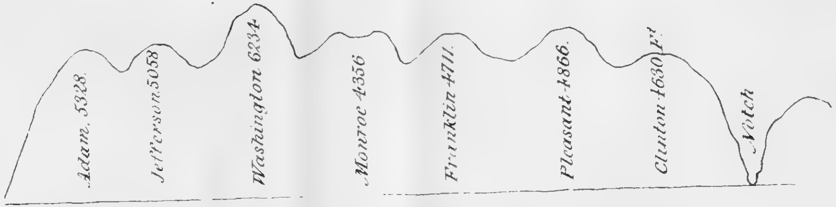

Adam. 5328.
Jefferson 5058
Washington 6234
Monroe 4356
Franklin 4711.
Pleasant 4866.
Clinton 4630 Ft
Notch

Fig. 2.

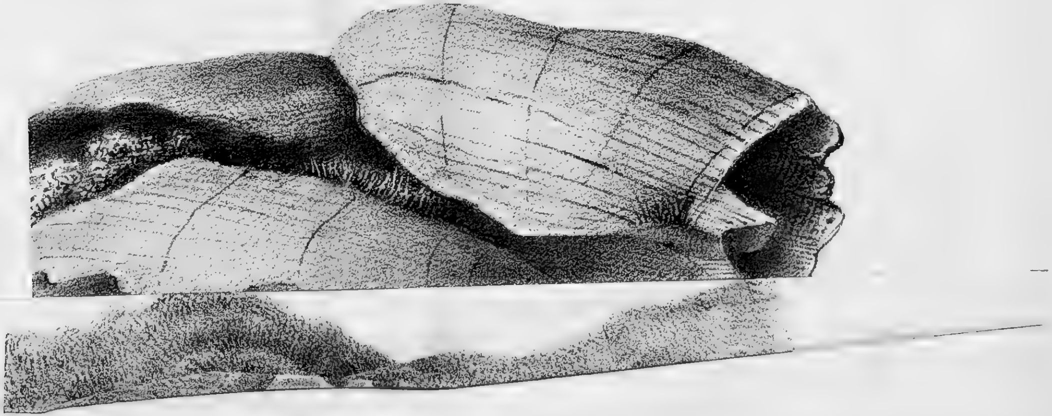
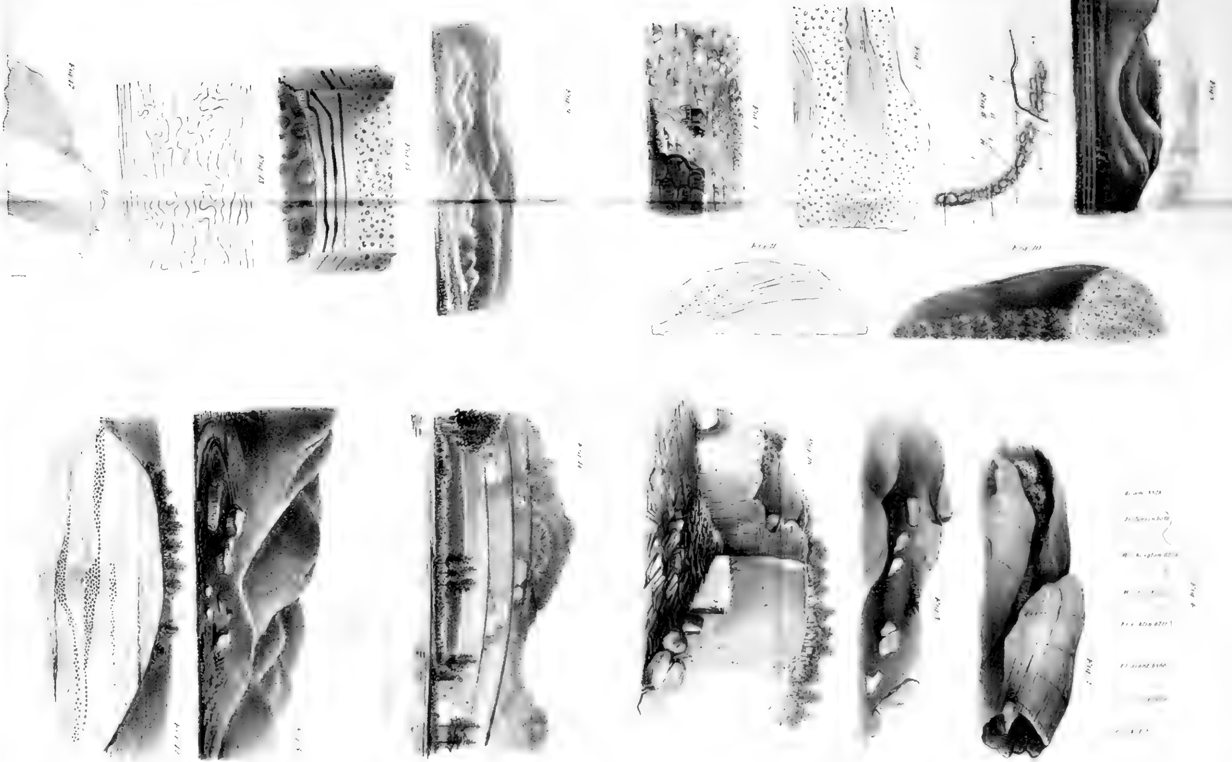
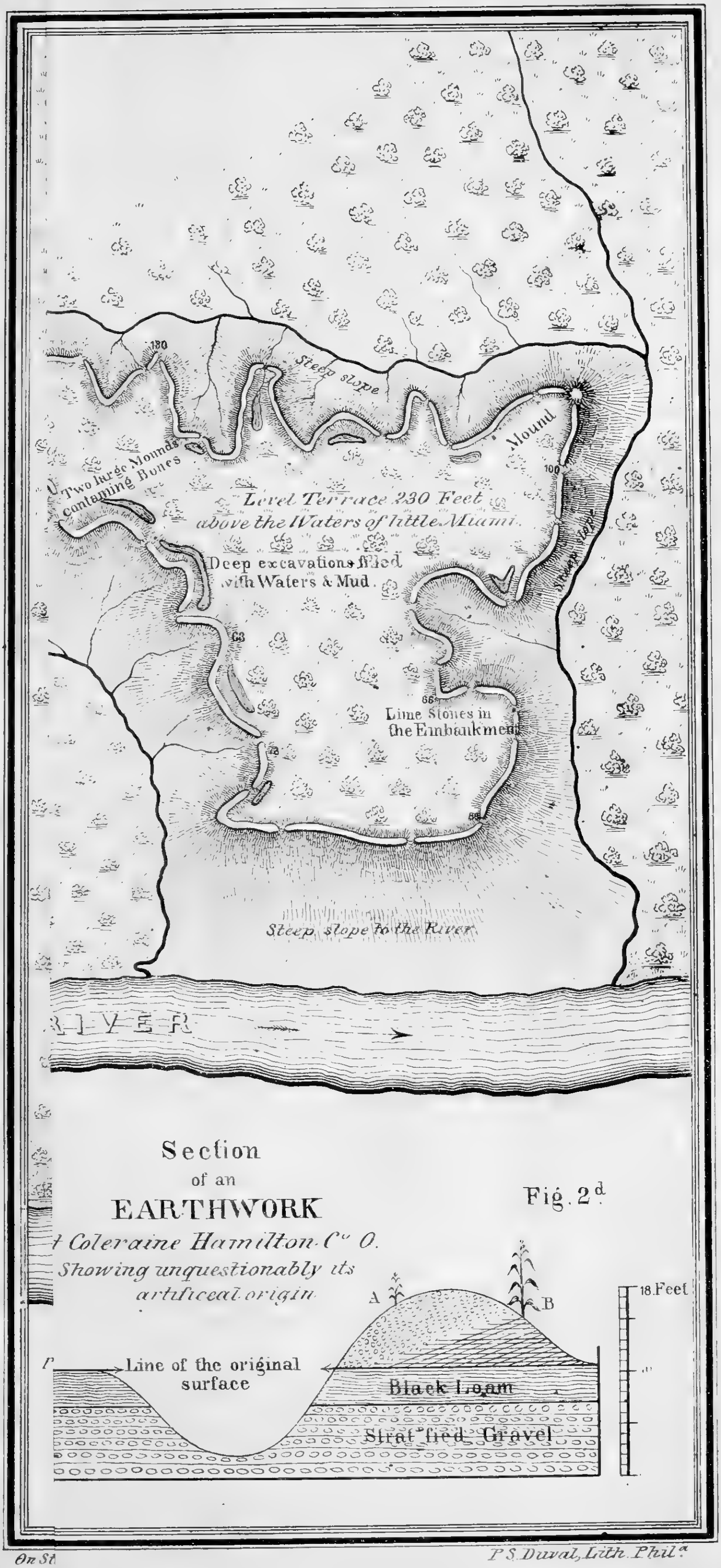
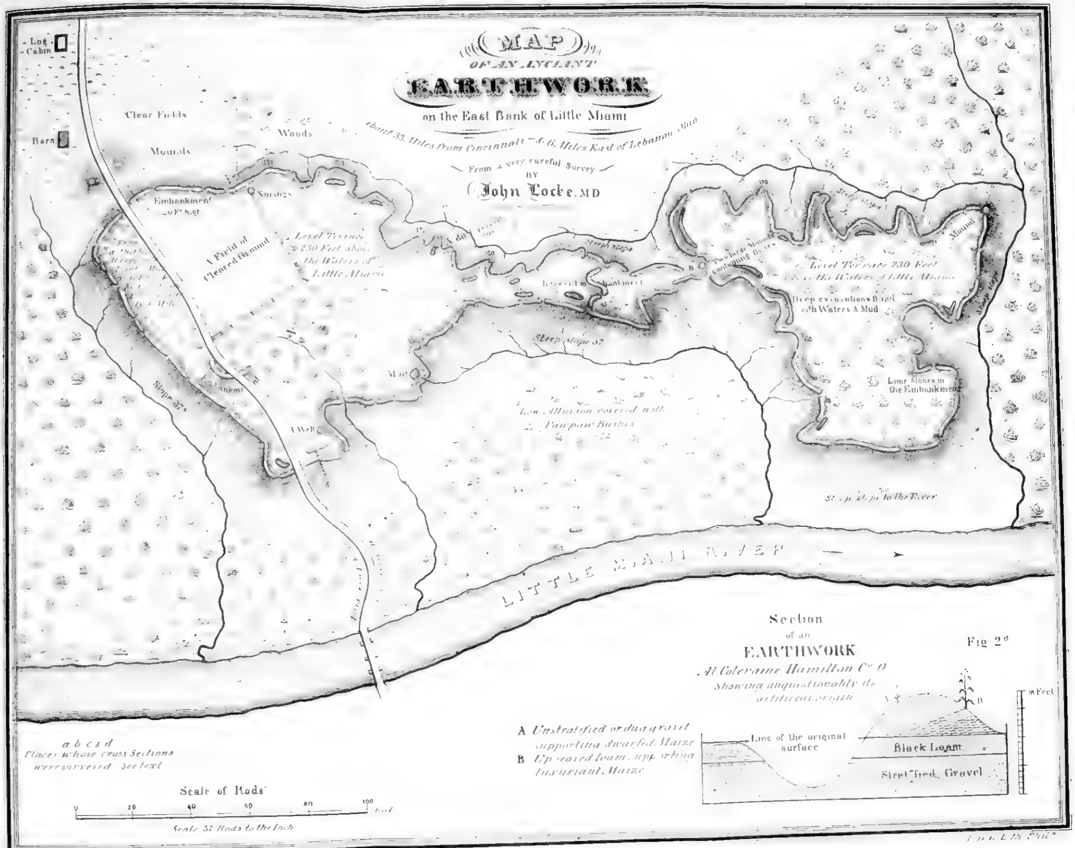


Plate VIII





On St. P. S. Duval, Lith. Phila.



On Stone by G. Schumacher

Plate XI

Fig. 3

Fig. 9

Fig. 7

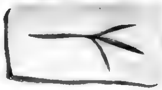


Fig. 8

Fig. 6

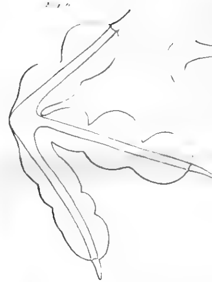


Fig. 5

Fig. 2

Fig. 1

Fig. 4

Plate XII.

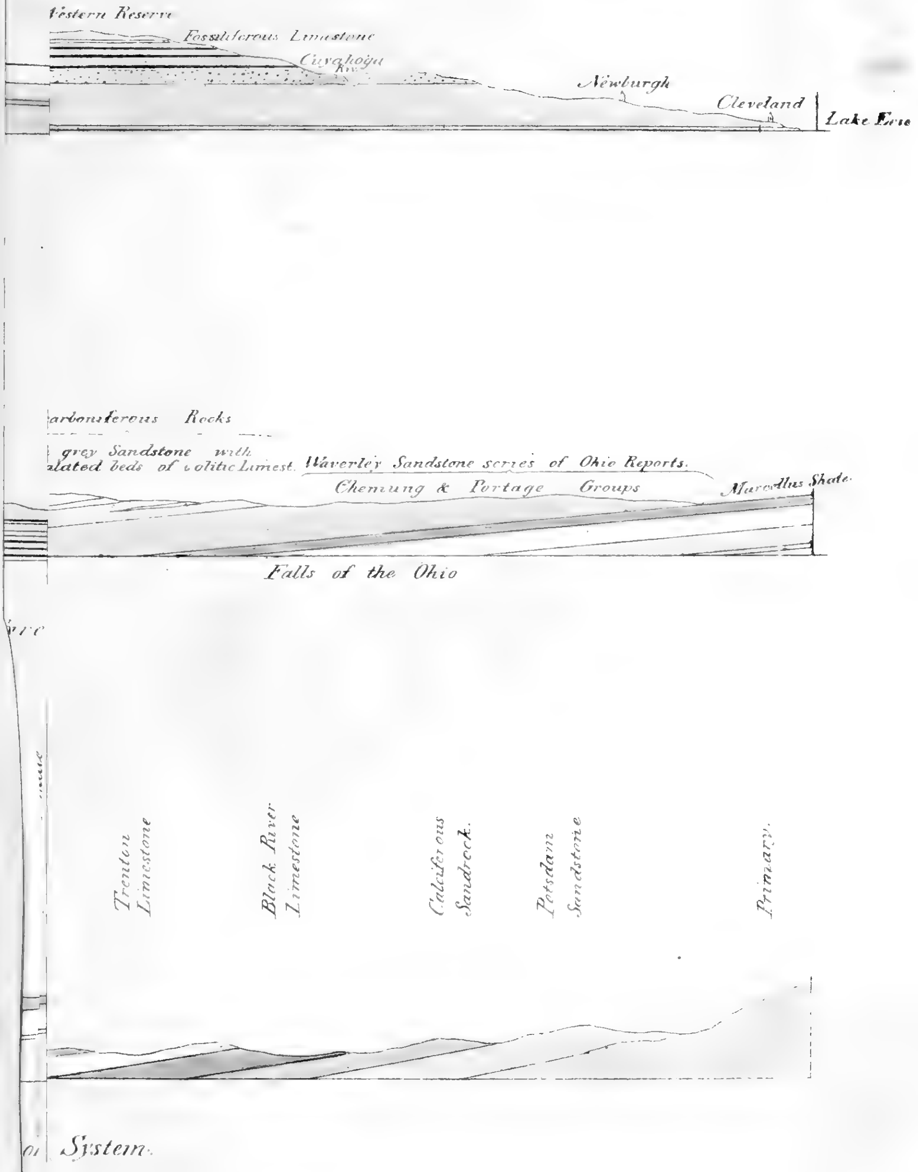

Vestern Reserve
Fossiliferous Limestone
Cuyahoga Riv.
Newburgh
Cleveland
Lake Erie
arboniferous Rocks
grey Sandstone with
alated beds of oolitic Limest.
Waverley Sandstone series of Ohio Reports.
Chemung & Portage Groups
Marcellus Shale
Falls of the Ohio
Trenton Limestone
Black River Limestone
Calciferous Sandrock.
Potsdam Sandstone
Primary.
System.

Plate XII

Plate XIV.

Tæniopteris Magnifolia ½ Size.

Lycopodites uncifolius.

Zamites obtusifolius.

Plate XIII.

Fig. 2

Fig. 1.

Fig. 3

Fig. 4.

Fig. 5.

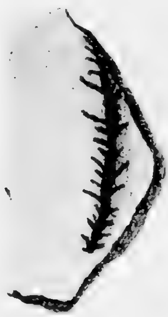
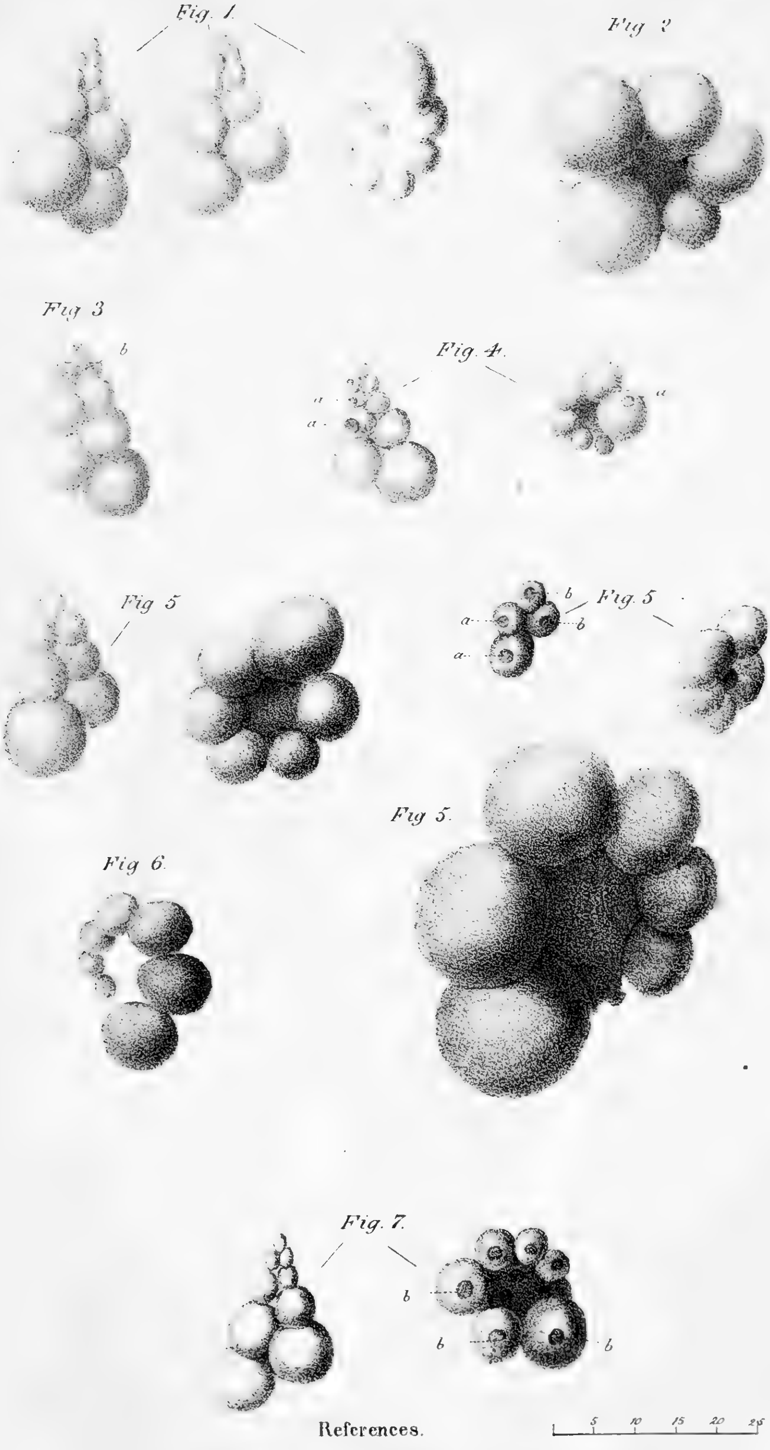


Plate XV.



References.

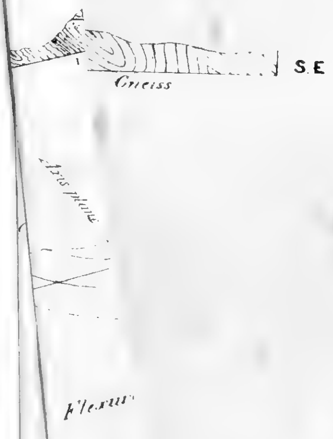
Fig. 1......Damascus. *Fig. 5.. Mt. of Olives*
„ 2&3. Eng: Chalk. *„ 6.. W. Side of Anti-Libanus.*
„ 4.... Missionary Station. *„ 7. . Beyrout.*

P S Duval Lith Phil^a

Plate XVI.

Section 4

Section 10.



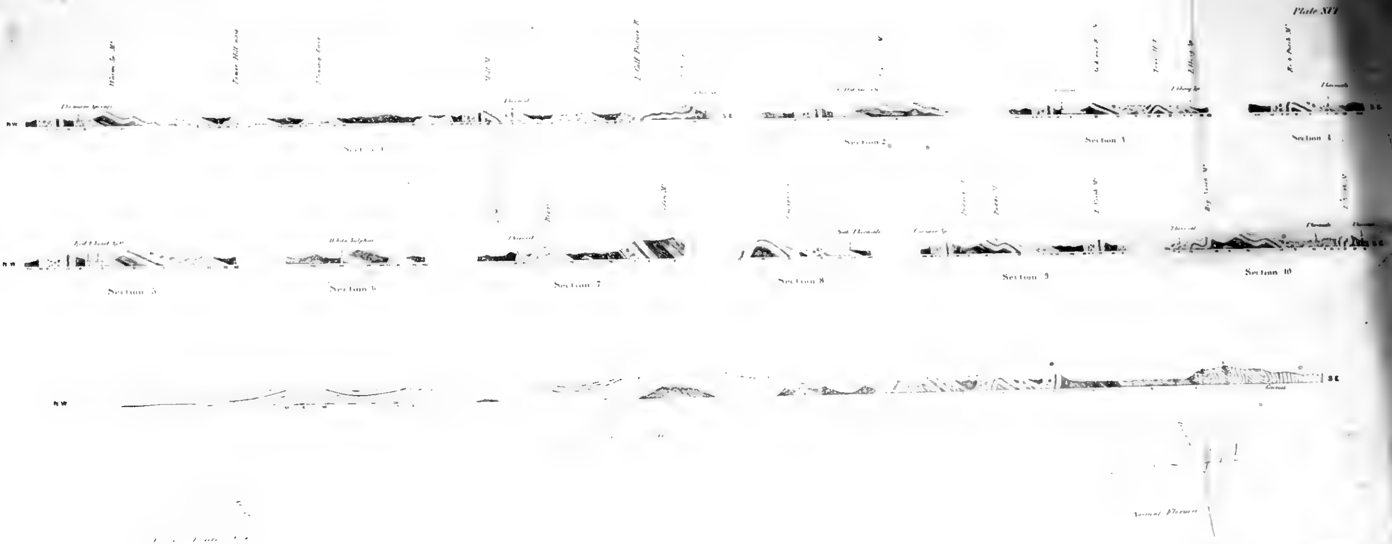
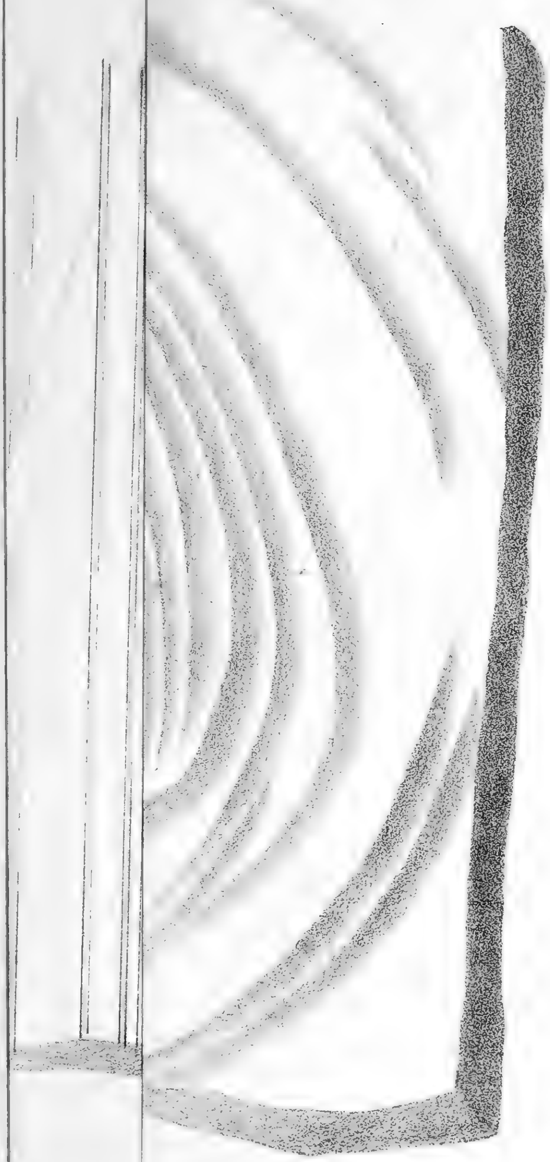


Plate XVI
Section 2
Section 3
Section 4
Section 5
Section 6
Section 7
Section 8
Section 9
Section 10

PL.XVII.

Fig.4.



Thayer & Co's Lith. Boston.

Thayer & Co. Lith Boston

PL. XVII

Fig 1

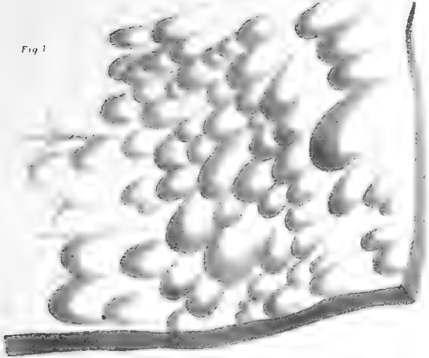


Fig 3

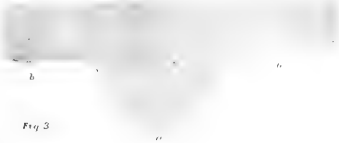


Fig 2

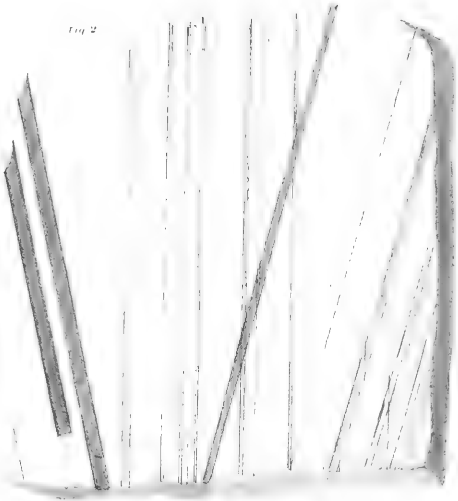
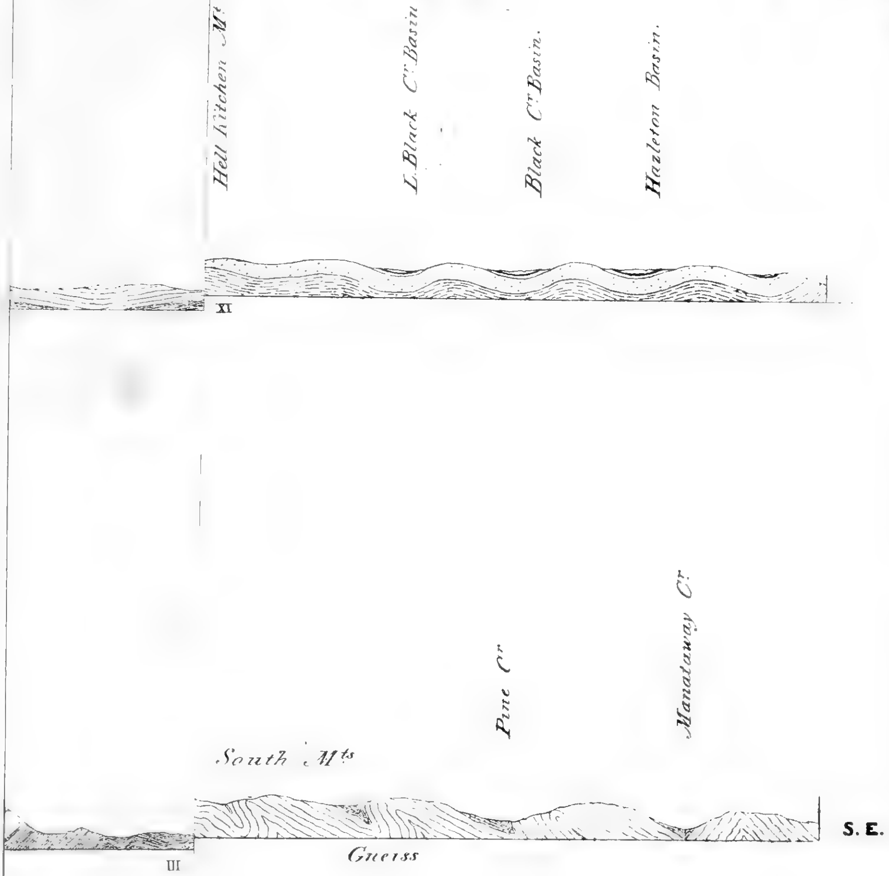


Fig 4

Thayer & Co. Lith Boston

Plate XVIII



Se

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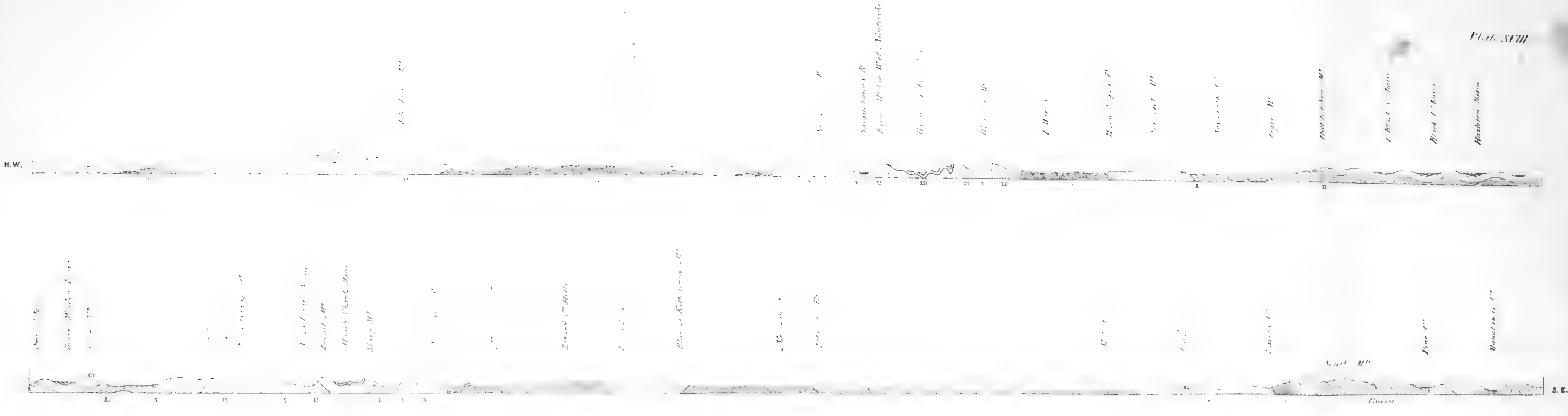
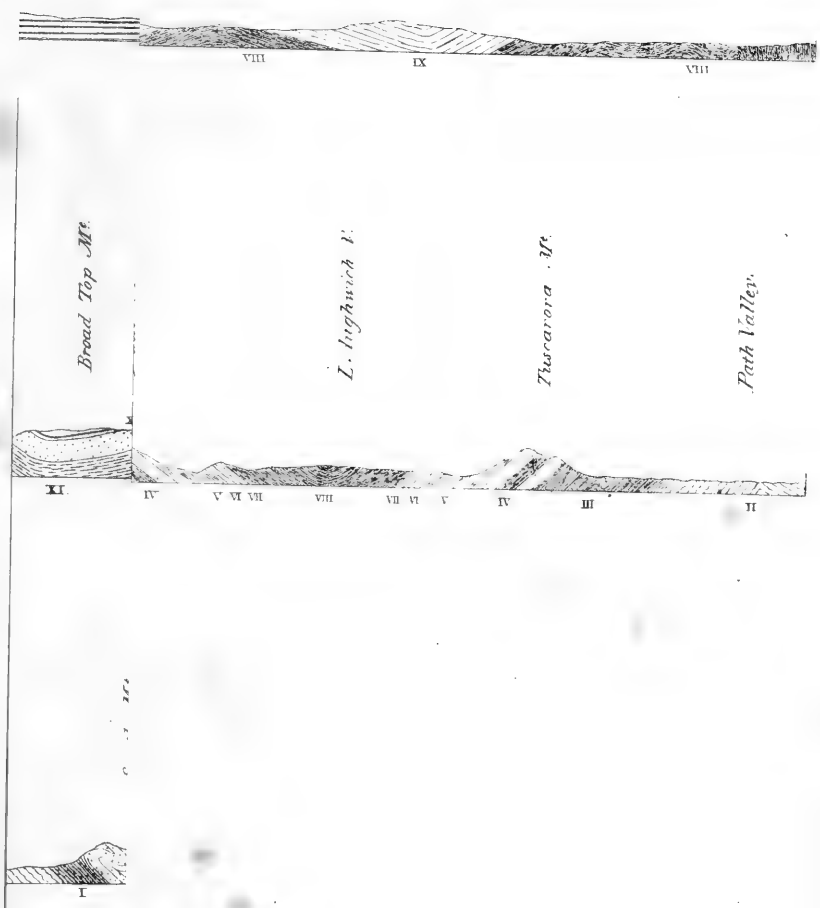
P. S.

Plate XVIII



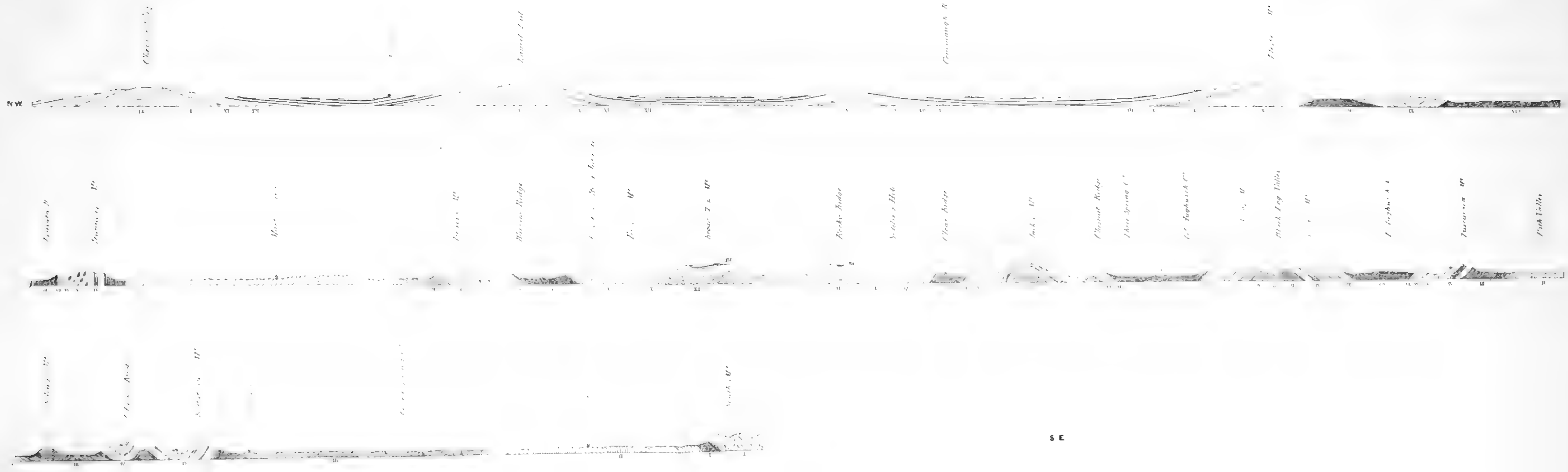
Section A.

Plate XIX.



enn^a thr

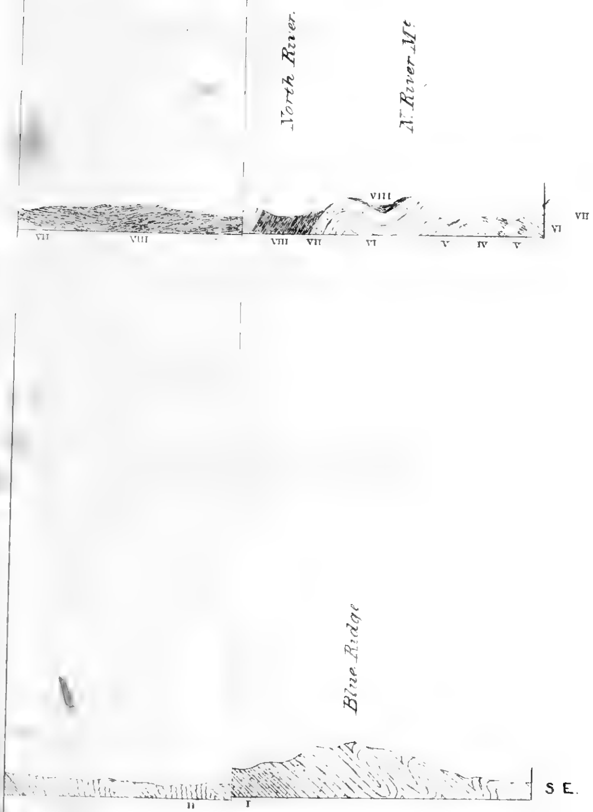
Plate XIX



Section B.

From Chesnut Ridge in Indiana County Penn^a through Armagh and Shippensburg to the South M^t in Cumberland County

Plate XX.

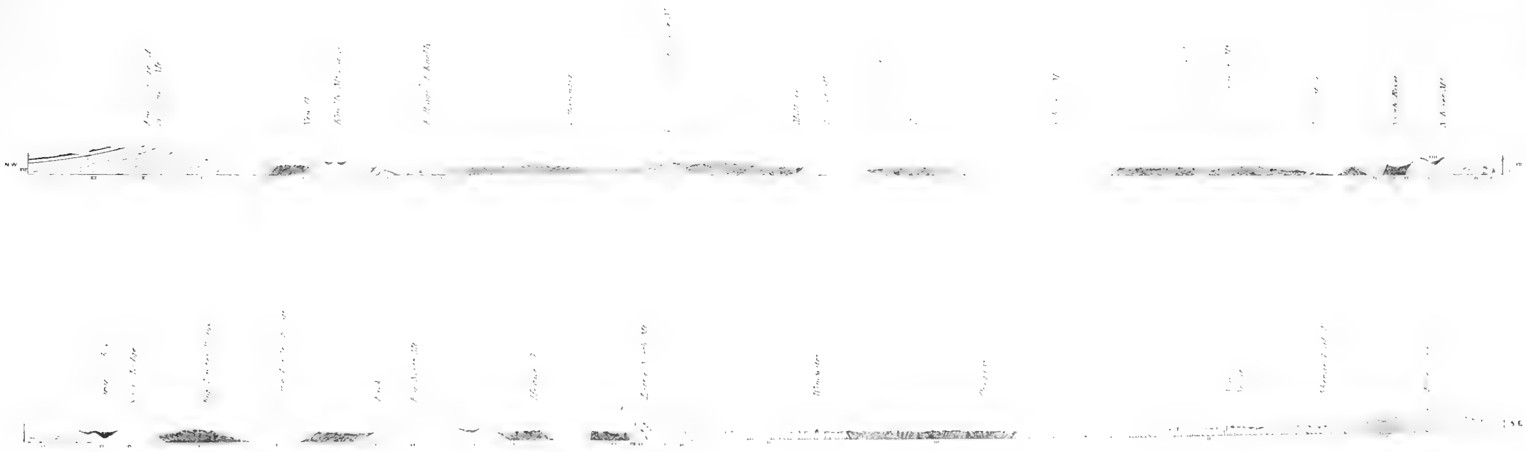


Secti

at Ashby's Gap

P S Dav

Plate XX



Section C

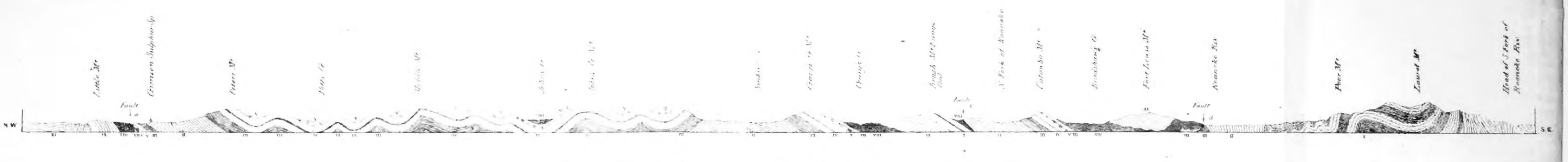
From Blue Ridge at [illegible] to Alleghany M. at N. W. Turnpike

Plate XXI.

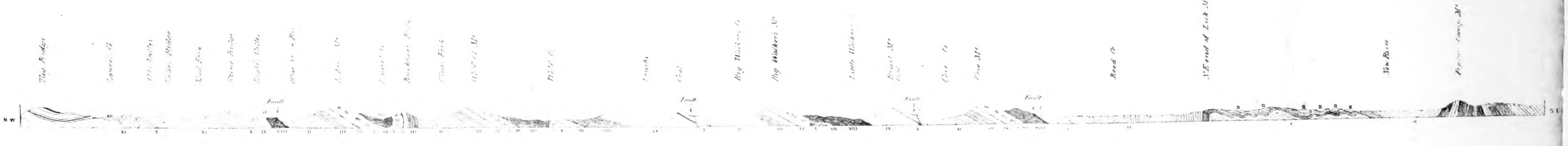
he Head of the So

Poplar Camp Mt a

Plate XXI.



Section D. From the Head of the South Fork of Roanoke Riv. to Little Mt. 5 M. from Union



Section E. From Poplar Camp Mt. at Poplar Camp to Fog Ridge West of Abbs Valley