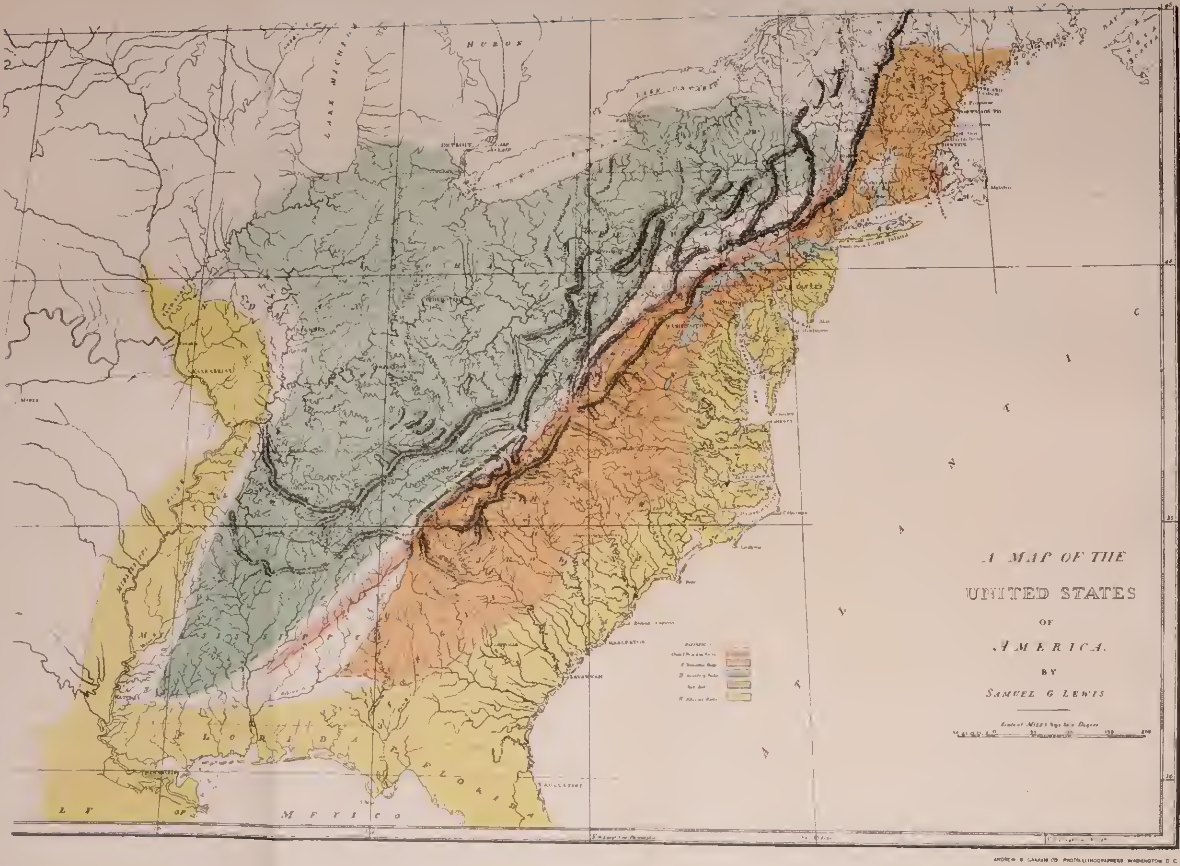
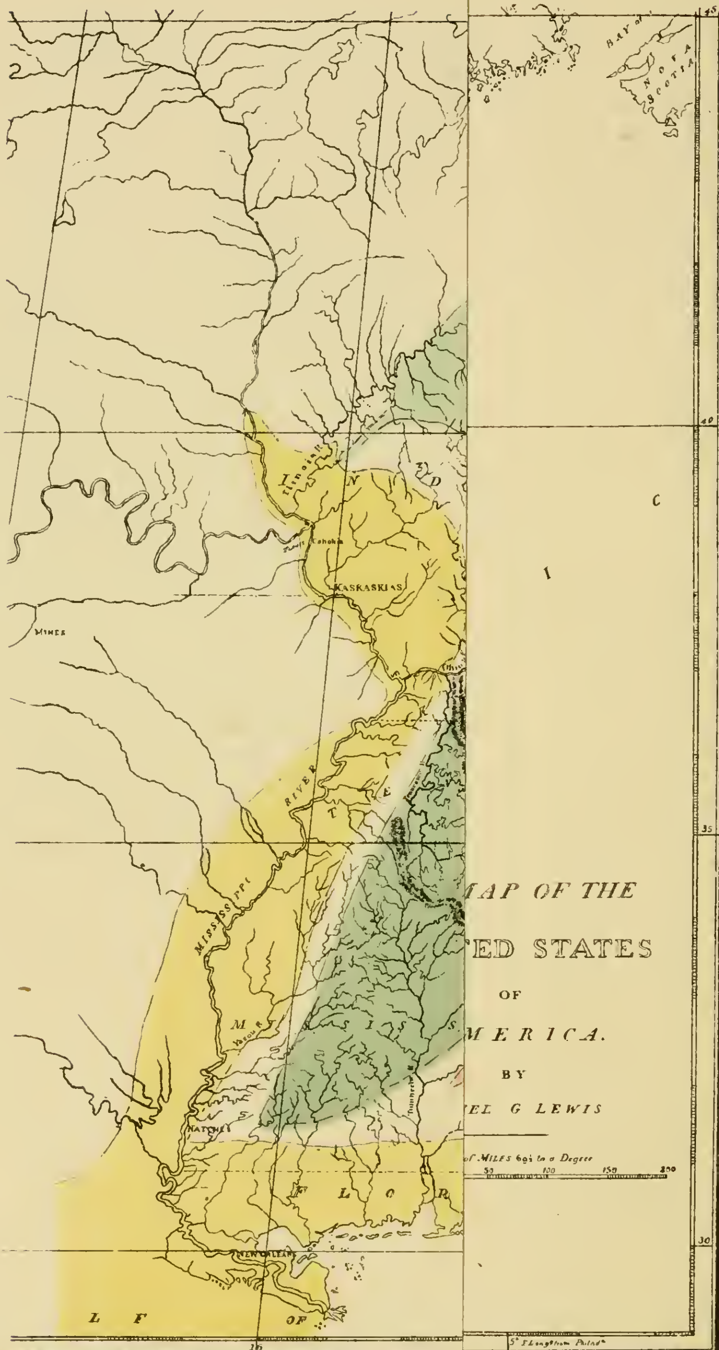


MACLURE'S GEOLOGICAL MAP OF THE UNITED STATES.

Reduced copy of original in Transactions of the American Philosophical Society, Vol. VI. Pt. 2. 1809.



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CONTRIBUTIONS TO THE HISTORY OF AMERICAN GEOLOGY.

BY

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The attainment of scientific truth has been effected to a great extent by the help of scientific error.—*Huxley.*

1901

PREFATORY NOTE.

The work herewith presented is in part an outgrowth of a series of lectures to students in geology in Columbian (now George Washington) University, though many of the facts were gathered while looking up the records of the early Government surveys, with a view of ascertaining the final disposition of their collections. No idea was at first entertained of putting the matter in book form, but as material gradually accumulated the advisability of making it a permanent record became apparent. On the supposition that it was a desirable thing to do at all, it is perhaps fortunate that the idea of a fairly consecutive history of the rise and progress of American geology was, like the science itself, a matter of growth, as the magnitude of the task would certainly have deterred from undertaking it one whose main opportunity lay in the improvement of odd moments.

As to the mode of presentation of the subject: It has been the writer's desire to do this in a manner such as should show not merely what has been done, by whom, and how it has been done, but the gradual growth of the science and the development of powers of observation and deduction as well. To do this satisfactorily, no other arrangement than a chronological one seemed possible, though it must be confessed that a topical one would have been easier to handle and could, perhaps, have been made more readable. In several instances, indeed, the topical treatment has been adopted, as in the chapters on the Eozoon and the Taconic question. Should it appear that the method is essentially similar to that adopted by Sir Archibald Geikie in his Founders of Geology, the writer has only to express the regret that the imitation is so crude.

Let no one for a moment feel that the writer has called attention to the errors and crudities of observation and deduction of the early workers in a spirit of levity. Far from that. These men were pioneers. They had received little or no preliminary training along these special lines, and had access to but few books. The information with which the geologist of to-day begins his career did not then exist, and an effort has here been made to show by what years of toil each new fact has been unearthed, cleansed of the débris which obscured its outlines, and treasured up in such form that it is now possible for the student, in a few short years, to encompass the garnerings of a century.

Nor must it be thought that in touching upon sundry disputes, quarrels, and petty jealousies it has been done with an idea of belittling the individual in any way. Indeed, a truly able man is not belittled by his weaknesses. To appreciate his strength we need to know his weakness. These were but men, and we, who are weakly human, like to recognize in them human traits—like to learn of their errors in judgment and wordy warfares.

Regarding the portraits, it may, perhaps, be well to state that a special effort has been made to obtain such as represented the individual at the period of his career under discussion. This has naturally been a matter of some difficulty, and in some cases an impossibility.

A large part of those here reproduced are from the G. Brown Goode collection in the National Museum and the private collection of the writer. For assistance in securing others the writer is indebted to Prof. W. H. Brewer, Prof. W. B. Clarke, Dr. W. H. Dall, S. F. Emmons, Dr. A. C. Peale, T. C. Weston, Gen. A. W. Vogdes, and others. Acknowledgments for other assistance are due to many, but particularly to Prof. Charles Schuchert, formerly of the National Museum, but now of Yale University. Miss Lucy M. Graves has rendered valuable assistance, both in preparation of the manuscript and reading the proof.

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CHAPTER I.

THE MACLUREAN ERA, 1785–1819.

In order that one may fully appreciate the conditions under which the early workers in geology in America labored, it is necessary to refer somewhat briefly to foreign workers and the general condition of the science at the time this history opens. A detailed statement is presumably unnecessary, the subject having been well covered by Lyell,[a] Geikie,[b] and Zittel.[c]

The literature extant at that time was not large, and was, moreover, for the most part quite inaccessible to the average American student. Libraries were few, small, and far between, and the workers, as a rule, men of moderate means who studied geology as a recreation or when the cares of their professions permitted.

Disregarding the cosmogonists—those who, to use a popular expression, did not allow what few facts they may have possessed to seriously hamper the flights of their imaginations—mention should be made of the writings of the French geologist, Güttard, during the period 1746–1765. Güttard studied the now well-known region of the Auvergne in central France, recognized the volcanic nature of the phenomena there displayed, and, though he fell into error when he attributed their origin to the combustion of petroleum or bitumen, he may, nevertheless, according to Doctor Geikie, be regarded as the founder of volcanic geology. Singularly enough, as it seems to-day, he failed to recognize the connection between volcanoes and basalt, and attributed the latter to crystallization from an aqueous solution. Güttard's papers were for many years lost sight of, but their value and interest have of late been made apparent by the author above quoted. Desmarest, who followed Güttard, corrected this error in his memoir on basalt, which appeared in 1774.

The geological results obtained by the Russian astronomical expedition under Pallas, in 1769, though important, could, for a long time at least, have had little effect on American workers, and then only through the writings of others. They were first published at St. Petersburg in German (1772–1776) and afterwards translated into French. Pallas taught, among other things, that a granite core was a

[a] Principles of Geology.

[b] The Founders of Geology.

[c] History of Geology and Paleontology.

constituent of all mountain ranges, and that the remains of the mammoth and other large animals found in Siberia and the Arctics were transported thence by floods from the region of the equator. This last idea, it will be noted, took firm hold on at least one of our American authors.

During 1779–1796 the Swiss naturalist, De Saussure, had put out three quarto volumes giving the results of his observations in the Alps, and Lehman and Fuchsel, during 1756–1770, had published important matter relative to the order of superposition of rocks. Fuchsel, unfortunately, wrote wholly in Latin, and though his observations were important they created little impression.

The two most prominent figures, and those whose views undoubtedly prevailed over all others, were the German, Werner, and the Englishman, Hutton. Indeed, our history opens in the very midst of a controversy between these two and their followers—between those who believed with Werner that the various rocks of the earth's crust were the result of a gradual precipitation from the waters of a universal ocean and who were not inaptly called *Neptunists*, and those who recognized the efficacy of igneous agencies and were therefore called *Plutonists*.

It is, of course, impossible to state in the majority of cases whence any writer may have drawn his inferences or inspiration. We may know the literature of any given period, but we have no means of knowing whether or not it was accessible to a writer or, indeed, if he was aware of its existence. Discoveries in science, like inventions, are rarely or never the work of a single brain, but are matters of growth. Such result from the gradual accumulation of facts or ideas, often seemingly wholly disconnected, but which some master mind takes at the proper time and molds to his uses.

What is commonly regarded as the first work on American geology was Johann David Schöpf's *Beitrage zur Mineralogischen Kenntniss von des Oestlichen Theils von Nord Amerika und seine Gebirge*, published in 1787. Schöpf came to America as a surgeon to the Hessian troops during the war of the Revolution, and immediately after the treaty of peace in 1783 made a tour throughout the Eastern States as far south as Florida.

Schöpf's Work on American Geology, 1787.

As a foreigner, whose results were published in Germany, Schöpf's work lies outside the limits of the present history. It may be said, however, that he noted the close similarity throughout all its parts of the flat lands (coastal plain) extending from the western end of Long Island to Florida, and that this was marked off from the hilly region to the northwest by a double series of waterfalls in all the rivers emptying into the Atlantic. Thus early was recognized the "fall line" as a physiographic feature of the American continent.

There are several brief papers of a mineralogical nature of an earlier date than Schöpf's, which may be mentioned. Thus, in the Memoirs of the American Academy of Arts and Sciences for 1785 are to be found the following titles:

Papers in Memoirs of American Academy, 1785.

An Account of the Oilstone found at Salisbury, by Samuel Webster; Yellow and Red Pigment, An account of, Found at Norton, by Samuel Deane; An Account of Several Strata of Earth and Shells on the Banks of the York River, Virginia, by Benjamin Lincoln; and Fossil Substance containing Vitriol and Sulphur, An Account of large quantities of, found at Lebanon, New Hampshire, by Jeremy Belknap.

Of more importance are two papers by David Jones and Caleb Alexander regarding the supposed volcanic nature of West River Mountain in Connecticut. Jones described in some detail the appearance of the mountain and the efforts of the natives, or *peasants*, as he called them, to discover thereon the gold which they imagined had been melted down to a solid body by the extreme heat of the eruption. The rock comprising the mountain was described as in many places much burned, softened, and dissolved by heat, with cinders and melted drops adhering and hanging down like small icicles, somewhat resembling in color the cinders of a furnace or black glass. While convinced that there had been volcanic explosions in the mountain, he regarded such as having taken place at least fifty years earlier, while the volcano itself, he thought, could not have been active perhaps "within the present nor past century."

Supposed Volcano in Connecticut.

Alexander wrote much more confidently:

> Once in winter there was an eruption. The years when the preceding eruptions happened I can not inform; the last was twenty-seven years since, which was the most violent eruption ever known in that place. It was toward the close of a dark evening when it was first perceived, being preceded by a louder noise than common; then directly was seen the fire, which was seen to burn for several hours.

After describing in some detail the appearance of the rock in the immediate vicinity of the spot from which the fire was supposed to have issued, Alexander went on to say:

> I am not able to determine whether there be anything of a sulphurous nature on this mountain, but this I dare affirm, that there have been several eruptions, but whether it may with propriety be called a volcano I know not. This determination is submitted to the judgment of gentlemen more acquainted with the nature of volcanoes than I can pretend to be.

In view of the definite nature of these statements, it may be well to anticipate, and to state here that in 1810 Col. George Gibbs visited the mountain, attracted by the published reports, and made known the results of his observations in Bruce's Mineralogical Journal. He found no trace whatever of any eruption nor other signs of volcanic activity, the "lava" reported proving to be hematite, an oxide of iron.

A paper by Robert McCauslin, read before the American Philosophical Society of Philadelphia in 1789 and published in 1793, conveys a good idea of the crude condition of analytical chemistry at that date and enables one to well appreciate the difficulties under which the mineralogists labored. In describing a "mineral substance" found near the falls of Niagara, he wrote:

Condition of Analytical Chemistry in 1789.

In order to determine the nature of this substance, I made the following experiments:

Exp. 1st. I put an opaque piece, weighting fourteen grains, into the vitriolic acid diluted with three times its quantity of water, and let it remain there twenty-four hours, shaking it now and then. Not the least effervescence ensued, and on taking out the piece it weighed near one grain more than when it was put in, although care was taken to absorb the moisture which was upon its surface. This experiment was repeated with a shining piece, and with exactly the same result.

Exp. 2nd. When put into vinegar it did not produce the least effervescence. The vinegar having stood upon it for sometime, it was then poured off and spirit of vitriol dropped into it, yet not the least precipitation ensued.

That I might not be led into error by the vinegar not being good of its kind, I repeated these experiments with chalk; and as both effervescence and precipitation took place it was evident there was no defect in the vinegar.

Exp. 3rd. A small piece was exposed to the heat of a blacksmith's forge during fifteen hours. Upon taking it out and pouring water upon it no ebullition ensued; nevertheless it tasted like weak limewater; being then divided into two portions, a solution of mild fixed alkali was dropped into the first, and immediately a precipitation ensued. The second portion being exposed to the air in a tea cup soon contracted a changeable film, which next morning was become very thick, resembling in every respect that of limewater.

Exp. 4th. Hot water being poured on some of this substance reduced to powder and the whole suffered to settle, the clear liquor had not the taste of limewater as in the 3rd experiment; nevertheless a solution of mild fixed alkali being dropped into it as copious a precipitation ensued as when the earth had undergone calcination.

As I had neither the nitrous nor muriatic acids, nor even caustic fixed alkali, I had it not in my power to make any trials with them.

From these experiments we may perhaps be authorized to draw the following conclusions:

1st. That this concrete is not an alkaline earth, as it is not affected either by the vitriolic or the vegetable acids.

2ndly. We may with more probability say that it is a combination of an acid with a calcareous earth, and that it might with propriety be ranked amongst the selenites. This supposition is founded on the following reasons: First, it appears from the fourth experiment that it is practically soluble in water, and that its earth can be precipitated by a mild fixed alkali; secondly, the third experiment shews evidently that its earth is of the calcareous kind, as appears by the styptic taste and changeable-colored film, agreeing exactly with common limewater. It seems probable that the vehemence of the fire had in part expelled the acid, leaving a portion of the mass in the state of quicklime.

Of more direct geological bearing is a letter from Benjamin De Witt to the Philadelphia Academy, printed in the second volume (1793) of their Transactions. He mentioned the occurrence of iron ore, gypsum, calcareous petrifactions, red, slaty stones, soft clay, a white fossil substance, rock crystal, a curious annular stone, and sixty-four specimens of some varieties of stone found on the shore of Lake Ontario. Discussing this last occurrence, he wrote:

De Witt on Origin of the Drift, 1793.

Now, it is almost impossible to believe that so great a variety of stones should be naturally formed in one place and of the same species of earth. They must, therefore, have been conveyed there by some extraordinary means. I am inclined to believe that this may have been effected by some mighty convulsion of nature, such as an earthquake or eruption; and perhaps this vast lake may be considered as one of those great fountains of the deep which were broken up when our earth was deluged with water, thereby producing that confusion and disorder in the composition of its surface which evidently seems to exist.

So far as I am aware, this is the first recognition of or attempt to account for the glacial drift, although its glacial character was of course undreamed of.

It is perhaps not strange that, with the cosmogonists not yet fully out of the field, the "many-sided" Franklin should have indulged in theories relative to the earth's history, nor that such were, at the time, thought worthy of consideration. In 1788, in a letter to the Abbé Soulavie, he suggested that the earth may not be solid to the core, but that the outer portion or shell is floating, as it were, on an internal fluid more dense than any solids of which we have knowledge. He was led to this view from seeing at the base of one of the Derbyshire, England, mountains, "oyster shells mixed in the stones," a condition of affairs indicating an elevation of this portion of the land above the sea level and which he conceived could not take place were the earth solid. He wrote:

Benjamin Franklin's Theories, 1788.

Thus the surface of the globe would be a shell, capable of being broken and disordered by any violent movements of the fluid on which it rested. And as air has been compressed by art so as to be twice as dense as water, in which case if such air and water could be contained in a strong glass vessel the air would be seen to take the lowest place and the water to float above and upon it; and as we know not yet the degree of density to which air may be compressed; and M. Amontons calculated, that its density increasing as it approached the center in the same proportion as above the surface, it would be at the depth of —— leagues heavier than gold, possibly the dense fluid occupying the internal parts of the globe might be air compressed. And as the force of expansion in dense air when heated is in proportion to its density; this central air might afford another agent to move the surface, as well as be of use in keeping alive the subterraneous fires; though as you observe, the sudden rarefaction of water coming into contact with those fires may also be an agent sufficiently strong for that purpose when acting between the incumbent earth and the fluid on which it rests.

If one might indulge imagination in supposing how such a globe was formed, I should conceive that all the elements in separate particles being originally mixed in confusion and occupying a greater space, they would, as soon as the Almighty fiat ordained gravity or the mutual attraction of certain parts and the mutual repulsion of other parts to exist, all move toward their common center; that the air being a fluid whose parts repel each other, though drawn to the common center by their gravity, would be densest toward the center and rarer as more remote; consequently all matters lighter than the central part of that air and immersed in it would recede from the center and rise till they arrived at that region of the air which was of the same specific gravity with themselves where they would rest; while other matter mixed with the lighter air would descend, and the two meeting would form the shell of the first earth, leaving the upper atmosphere quite clear. The original movement of the parts toward their common center would naturally form a whirl there, which would continue in the turning of the new-formed globe upon its axis, and the greatest diameter of the shell would be in its equator. If by any accident afterwards the axis should be changed, the dense internal fluid by altering its form must burst the shell and throw all its substance into the confusion in which we find it.

Again, in a letter to Mr. Bodoin, under date of 1790, he said:

Let me add another question or two, not relating, indeed, to magnetism, but, however, to the theory of the earth.

Is not the finding of great quantities of shells and bones of animals (natural to hot climates) in the cold ones of our present world some proof that its present poles have been changed? Is not the supposition that the poles have been changed the easiest way of accounting for the deluge by getting rid of the old difficulty how to dispose of its waters after it was over? Since, if the poles were again to be changed and placed in the present equator, the sea would fall there about 15 miles in height and rise as much in the present polar regions, and the effect would be proportionable if the new poles were placed anywhere between the present and the equator.

Does not the apparent wrack of the surface of this globe, thrown up into long ridges of mountains, with strata in various proportions, make it probable that its internal mass is a fluid, but a fluid so dense as to float the heaviest of our substances? Do we know the limit of condensation air is capable of? Supposing it to grow denser within the surface in the same proportion nearly as we find it does without, at what depth may it be equal in density with gold?

Can we easily conceive how the strata of the earth could have been so deranged if it had not been a mere shell supported by a heavier fluid? Would not such a supposed internal fluid globe be immediately sensible of a change in the situation of the earth's axis, alter its form, and thereby burst the shell and throw up parts of it above the rest?

As if we would alter the proportion of the fluid contained in the shell of an egg and place its longest diameter where its shortest now is the shell must break if the whole internal substance were as solid and hard as the shell.

Might not a wave by any means raised in this supposed internal ocean of extremely dense fluid, raise in some degree as it passes the present shell of incumbent earth and break it in some places, as in earthquakes? And may not the progress of such wave and the disorders it occasions among the solids of the shell account for the rumbling sound being first heard at a distance, augmenting as it approaches, and gradually dying away as it proceeds? A circumstance observed by the inhabitants of South America in their last great earthquake—that noise coming from a place some degrees north of Lima and being traced by enquiry quite down to Buenos Ayres, proceeding regularly from north to south at the rate of —— leagues per minute, as I was informed by a very ingenious Peruvian whom I met in Paris.

Franklin was not the only one of our statesmen who at that time felt at liberty to indulge in study and speculation on scientific subjects. Thomas Jefferson, when he came to Phiiladelphia to be inaugurated Vice-President in 1797, brought with him a collection of fossil bones from the western part of Virginia, and the manuscript of a memoir upon them, which he read before the American Philosophical Society, of which he had been elected president the preceding year.[a] And again in 1801, when Congress was vainly trying to untangle the difficulties arising from the tie vote between Jefferson and Burr, when every politician at the Capitol was busy with schemes and counter-schemes, Jefferson was corresponding with Doctor Wistar in regard to some bones of the mammoth which he had just procured from Shawangunk, in New York; and still again, in 1808, when the excitement over the embargo was highest, and when every day brought fresh denunciation of him and his policy, he was carrying on his geological studies in the White House itself. Under his direction upward of three hundred specimens of fossil bones had been brought from the famous Big Bone Lick, of Kentucky, and spread in one of the large unfinished rooms of the Presidential Mansion. The exploration of this lick, it should be noted, was made at the private expense of Jefferson, through the agency of Gen. William Clarke, the western explorer.[b]

Jefferson as a Paleontologist, 1797.

The appearance of bones of animals of large size and now extinct, as described by Jefferson, naturally excited the attention of the curious, and numerous accounts of similar occurrences began to find their way into print. In the Transactions of the American Philosophical Society, under date of 1802, is given an abstract of a communication by Martin Duvalde regarding the finding of bones supposed to be those of an elephant in the Opelousas country west of the Mississippi, i. e., in Louisiana.

Of greater interest, however, is a paper by the artist and naturalist, Rembrandt Peale, entitled Account of the Skeleton of the Mammoth, A Nondescript Carnivorous Animal of Immense Size Found in America. This was printed in London under date of 1802, and dedicated to Sir Joseph Banks, Bart., President of the Royal Society. The particular skeleton described was exhumed in the vicinity of Newburgh, New York, in 1801.[c] The animal was regarded by Peale as unquestionably carnivorous from

Peale's Account of the Mammoth, 1802.

[a] This paper was published in the Transactions of the Society, IV, 1799, as was also Doctor Wistar's more detailed description of the bones themselves.

[b] The Origin of the National Scientific and Educational Institutions of the United States, by G. Brown Goode.

[c] Sufficient material was found to form two skeletons, one of which was sent to London and the other to Philadelphia, where it was subsequently destroyed by fire.

the structure of the teeth and jaw, and he concluded his description with a quotation from Doctor Dunter:

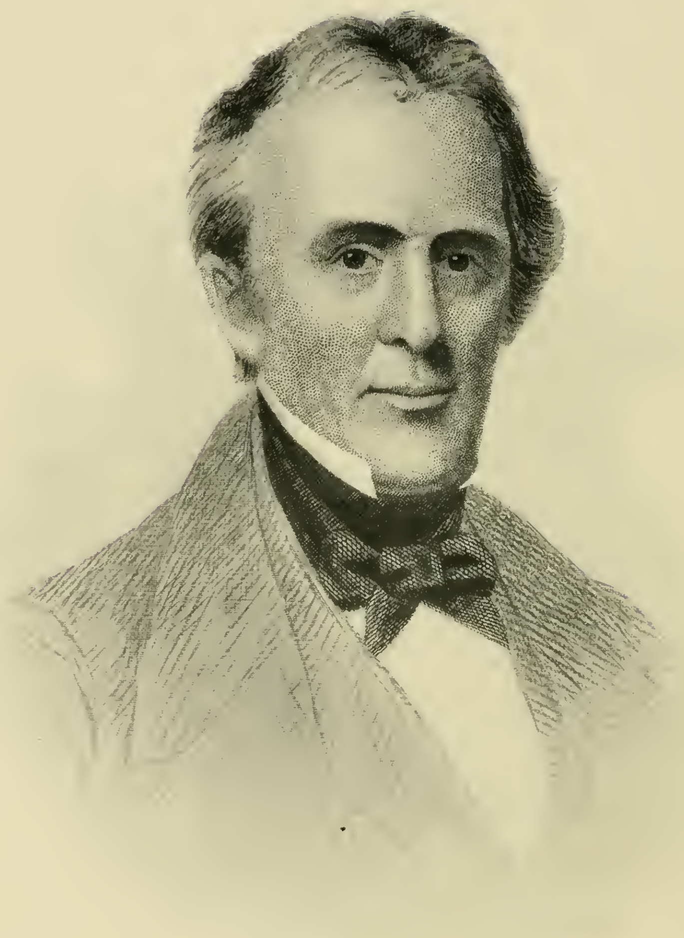
If this animal was indeed carnivorous, which I believe can not be doubted, though we may as philosophers regret it, as men we cannot but thank Heaven that its whole generation is probably extinct.[a]

Turning once more to the Transactions of the American Philosophical Society, we find in 1799 Thomas P. Smith giving an account of "crystalline basalts" found in the Conewago Hills, near Elizabethtown in Pennsylvania. The "crystals" were described as generally tetrahedral and of very fine grain. The massive, noncolumnar form was spoken of as amorphous, but it "has generally a very strong tendency to crystallize." Crystallized granite in predominating tetrahedral forms was also described. In the same transactions (1807) S. Godon made certain observations for a mineralogical map of Maryland, in which he noted the occurrence of gneiss and greenstone in the the vicinity of Washington, and the finding of "fossil bodies," shells, and fossil woods in a ravine near Rock Creek Church. The city itself was rightly described as built on alluvial land, Rock Creek forming the boundary between the primary and alluvial soil.

Smith's Account of the Conewago Hills, 1799.

In February of this same year B. H. Latrobe read before the society a paper describing the geographic distribution of the sand rock quarried at Aquia Creek on the Potomac, and used in some of the public buildings of Washington. The marked cross-bedding, so prominent a feature in the stone, he ascribed to wind action. A fact of more geological importance is, however, his recognition of the "fall line"—of the fact that a line drawn along the lower falls of our rivers is the ancient line of the seacoast from New York to the southwest, and indicates a higher ocean level of some 120 feet. Schöpf, it will be remem-

[a] The first mention of bones of the American mammoth upon record appears to be that made by Dr. Cotton Mather, of Boston, in a paper communicated to the Royal Society in 1714. The object of this worthy divine seems to have been to corroborate, by the discovery of the bones, the account given in Scripture of a race of antediluvian giants. He inclines to this opinion from the circumstance that bones have been dug up in America of an enormous size, and yet resembling in their formation those of the human body. These bones, he states, were found in 1705 near Albany, on the Hudson. Among them was a grinder weighing $4\frac{3}{4}$ pounds; another tooth, broad and flat, like an incisor; a third like the eye tooth of man when worn away by mastication, and a bone, supposed to be that of the thigh, which was 17 feet in length. The ground for 75 feet around the spot where these bones were discovered he asserts to have been of a different color and substance from the surrounding, a difference which he attributes to the effects produced by the rotting of the flesh of the animal. Some of these bones were found at a distance of 50 leagues from the sea, and at a great depth in the earth. An account, so manifestly tinctured by credulity and evincing such entire ignorance of anatomy, excited but little attention in the scientific world, and scarce any further notice of these bones can be found for nearly thirty years.—An Account of the Fossil Bones of the Great American Mammoth, by John Ward, M. D., in Boston Journal of Philosophy, I, 1823–24, pp. 263, 264.



BENJAMIN SILLIMAN.

Professor of Chemistry, Yale College.

bered, recognized this fall line, though it does not appear that he put a like interpretation upon the phenomenon.

At this date, it is well to note, none of the sciences were taught in the colleges and other institutions of learning in America. Indeed, the general trend of public opinion was decidedly against the study of geology or the investigation of any question which might lead to the discovery of supposed inconsistencies in the Mosaic account of creation or to conclusions in any degree out of harmony therewith. The movement, therefore, by Professor Dwight in 1798 toward the establishment in Yale College of a department for the teaching of these subjects, was of the greatest importance and of far-reaching consequences. This movement culminated in 1802 with the appointment of Benjamin Silliman to the professorship of chemistry and natural science in that institution. Silliman was at that time about twenty-two years of age, only recently admitted to the bar, and was serving as a tutor in law, with not even the most rudimentary knowledge of the science he was to teach. He wrote:

Appointment of Benjamin Silliman at Yale, 1802.

The appointment was of course the cause of wonder to all and of cavil to political enemies of the college. Although I persevered in my legal studies * * * I soon after the confidential communication of President Dwight [informing him of his probable appointment] obtained a few books on chemistry and kept them secluded in my secretary, occasionally reading in them privately. This reading did not profit me much. Some general principles were intelligible, but it became at once obvious to me that to see and perform experiments and to become familiar with many substances was indispensable to any progress in chemistry, and of course I must resort to Philadelphia, which presented more advantage to science than any other place in our country.[a]

To Philadelphia he accordingly went in the autumn of 1802, remaining for nearly five months attending the lectures on chemistry given by Dr. James Woodhouse in the Medical School of Philadelphia. His own first lecture at Yale was delivered April 4, 1804, while in his twenty-fifth year, in a room in Mr. Tuttle's building on Chapel street.

Few geological papers bear Silliman's name, and he is better known as a teacher and public lecturer. That which, however, has tended more than anything else to keep him in constant remembrance is his American Journal of Science, founded in 1818, some eight years after the suspension of the American Journal of Mineralogy, to be noted later. The publication has continued down to the present day, and it is therefore one of the oldest and perhaps the most important geological periodical extant in America.

Silliman resigned his professorship in 1849 and died on December 24, 1864, having through his own efforts as a teacher, but more particularly through his personal influence as a writer and lecturer, probably done more to advance the science of geology than any man of his day. Nevertheless, looking down the vista of a hundred years of

[a] G. P. Fisher, Life of B. Silliman. New York, 1866.

advancement, the spectacle of this young lawyer secluding in his desk sundry books which he read privately in order to fit himself for the position of a professorship in Yale is edifying to say the least.

On January 1, 1800, the Connecticut Academy of Sciences had addressed a circular letter to every town in the State, containing subjects of inquiry arranged under thirty-two distinct heads, and requesting answers. To the fifth of these inquiries Silliman responded in 1806 with a sketch of the mineralogy of the town of New Haven. This was published in the Transactions of the Society in 1810, and is of interest as being the first attempt at a geological description of the region, as well as being Silliman's first attempt at a geological survey.

Silliman's Mineralogy of New Haven, 1806.

With much laborious argument he showed that the town of New Haven is itself situated on an alluvial plain. East Rock he described as a whinstone, trap, or basalt, identical with that from the Salisbury Craig near Edinburgh, Scotland.

> The stone is reckoned among the argillaceous clays by some mineralogists and by others among the siliceous. The predominant ingredient is certainly silex or flinty earth, although when breathed upon it emits the smell of clay, which would induce one to refer it to the argillaceous family.

He would account for its presence on the supposition that it had—

> actually been melted in the bowels of the earth and ejected among the superior strata by the force of subterraneous fire, but never erupted like lava, cooling under the pressure of the superincumbent strata and therefore compact or nonvesicular, its present form being due to erosion.

Thus, at this early date and with a very limited amount of experience, Silliman was able to discriminate between effusive and deep-seated rocks. The rock resting upon the sandstone to the southeast of East Rock he found somewhat puzzling. "We must pronounce it granitic, although it is not a granite, and inclined to whin, although it is not a whinstone," he wrote, finally concluding that it formed a connecting link between granite and whinstone. Pine Rock and West Rock were also identified as whin rock and basalt resting upon sandstone. Quartz and sandstone found at Westfield and at the Derby pike were referred to as "micacious and magnesian schistus." He modestly concluded his paper by adding:

> If there are errors (in the above) they are not the result of indolent and remiss inquiry, but of deficient information or erroneous judgment.

In these same Transactions, under date of 1808, Silliman, in conjunction with Professor Kingsley, gave a very full account of the meteorite that fell in Weston, Connecticut, the year previous. This was the first really scientific description of the phenomena attending the fall of one of these bodies, as well as of its mineral nature, that had, up to that time, been given in America, and it attracted widespread attention. It was this account concerning which Jefferson is said to have remarked: "It is

The Weston Meteorite, 1808.

easier to believe that two Yankee professors will lie than to admit that stones can fall from heaven."[a]

A pudgy duodecimo volume of some 500 pages, from the pen of a Dr. James Mease, and bearing the date 1807, may be mentioned here, not so much on account of the scientific value of its contents as the pretentiousness of its title: A Geological Account of the United States, Comprehending a short Description of their Animal, Vegetable, and Mineral Productions, Antiquities, and Curiosities. The portion really geological comprises some 30 pages, though 25 more are given up to a catalogue of minerals. The geological part is acknowledgedly a compilation from the writings of Volney, Mitchill, and others. The country is divided into (1) granitic region, (2) region of sandstone, (3) calcareous region, (4) region of sea sand, and (5) region of river alluvions, the boundaries of each of which are given in some detail. The truly scientific character of the work is shown by the following quotation taken from a description of the narrows of the Connecticut River.

Mease's Geological Account of the United States, 1807.

No living creature was ever known to pass through this narrow except an Indian woman, who was in a canoe, attempting to cross the river above it, but carelessly suffered herself to fall within the power of the current. Perceiving her danger she took a bottle of rum she had with her and drank the whole of it; then lay down in her canoe to meet her destiny. She marvelously went through safely, and was taken out of the canoe some miles below quite intoxicated.

The year 1809 must ever be notable in the history of American geology, since it brought forth Maclure's Observations on the Geology of the United States, with a colored geological map of the region east of the Mississippi. With the exception of Güttard's mineralogical map of Louisiana and Canada, published in 1752, it was the earliest attempt at a geological map of America, and has caused its author to become known as the father of American geology and the William Smith of America.[b]

Maclure on the Geology of the United States, 1809.

Maclure's personal history is not without interest in itself, and is worthy of note here on account of his relation to American science and as illustrating the conditions under which a man at that date could rise to prominence in geological circles with little or no preliminary training.

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[a] G. Brown Goode, Beginnings of American Science. This writer, however, discredits the authenticity of the report, regarding it one of the millions of slanders to which Jefferson was subjected in those days.

[b] See article by J. W. Judd, Geological Magazine, London, October, 1897, for account of Smith's work. What is believed by Professor Judd to be actually the first geological map in existence is one of Smith's, published in 1799. This bears the following title: A map of five miles around the City of Bath (England), on a scale of one inch and a half to the mile, from an actual survey, including all the new roads, with alterations and improvements to the present time (1799), printed for and sold by A. Taylor and W. Moyler, booksellers, Bath.

The map by Cuvier and Brongniart of the environs of Paris bears the date of 1809, which is the same as that of the first edition of Maclure's.

He was born at Ayr, Scotland, in 1763, and first came to America at the age of nineteen, with a view to mercantile employment, subsequently returning to London, where he commenced his career of commercial enterprise as a partner in the house of Miller, Hart & Co. He seems to have been remarkably successful, and accumulated a considerable fortune. In 1796 he again visited America and, it is stated, took the necessary steps for becoming an American citizen.

He was a liberal patron of science, and for twenty-two years, beginning with December, 1817, was president of the Philadelphia Academy of Natural Sciences, to which institution he subsequently donated his valuable private library and some $20,000 in money.

After retiring from business, and prior to 1809, Maclure spent several years in England and on the continent of Europe, traversing the most interesting portions of the Old World from the Mediterranean Sea to the Baltic and from the British Isles to Bohemia. On returning to America he took up the important enterprise, noted above, of preparing a geological map of the United States. To accomplish this, in the language of his biographer:

> He went forth with his hammer in hand and his wallet on his shoulder, pursuing his researches in every direction, often amid pathless tracts and dreary solitudes, until he had crossed and recrossed the Allegheny Mountains no less than fifty times. He encountered all the privations of hunger, thirst, fatigue, and exposure, month after month and year after year, until his indomitable spirit had conquered every difficulty and crowned his enterprise with success.

Like several of the scientists of his time, Maclure in 1824 became interested in the communistic society at New Harmony, Indiana, founded by the elder Owen. He was, however, seriously disappointed in the outcome and withdrew about 1827.

It was, presumably, during his connection with this association that he is quoted as refusing to invest money in real estate in the city of Philadelphia, saying:

> Land in the cities can no longer rise in value. The communistic society must prevail, and in the course of a few years Philadelphia must be deserted; those who live long enough may come back here and see the foxes looking out of the windows.

Opinions like this and those which follow are quoted here, not for the purpose of belittling Maclure in the least, but as showing how impossible it was at that time for any man to realize all that was in store for the United States.

The possibilities of railroad transportation were scarcely dreamed of, and mountain barriers and desert plains were looked upon as natural boundaries between various peoples. From an examination of maps of the United States, Maclure was inclined to divide the country into three distinct and separate parts, differing materially from each other in their relative situation and in their means of communication

WILLIAM MACLURE.

President of the Philadelphia Academy of Natural Sciences.

with the rest of the globe. The natural line of separation between the two main divisions was that formed by the Allegheny Mountains, which, from the poorness of the soil and the difficulty of access to market, he regarded as probably the last portion of the continent to become thickly inhabited.

To the west of this range was the Mississippi basin, which, in his view, was destined, on account of climate and soil, to become a country of immense agricultural capabilities. Traversed by only one great river, which is practically inaccessible to large ships of war, this section, inclosed by the Alleghenies on the east, the Rockies on the west, and the Lakes at the north, he felt to be guarded against invasion by the comparative weakness of their mountain neighbors and the impossibility of attack by sea. It would therefore be given over to a nation of agriculturalists, the rulers of which would by nature be deprived of even an excuse for keeping either a fleet or army such as had in the past always brought about the ruin of free and equal representative governments.

He wrote:

On this earth or in the page of history it is probable no place can be found of the same extent so well calculated to perpetuate a free and equal representative government as the basin of the Mississippi, both from its physical advantages and the political constitutions on which the state of society is bottomed.

The people of the Atlantic slope, he felt, would, however, labor under entirely different conditions. Placed on an extensive coast, accessible at all points, with numerous rivers, they were liable to the depredations of a superior fleet and would naturally become a military people and involved in wars with European nations.

Maclure's observations, as already noted, were made in almost every State and Territory in the Union, from the river St. Lawrence to the Gulf of Mexico, and the memoir which embraces the accumulated facts was submitted to the American Philosophical Society and printed in their Transactions in 1809. The map of this issue is interesting not alone for its geological coloring, but as showing the paucity of knowledge regarding the physical features of the continent. (See Plate 1.) Thus, a continuous range of mountains was figured as extending from northern Maine, along its western boundary, through eastern Vermont, western Massachusetts, across southeast New York and New Jersey to Pennsylvania. More or less parallel ranges were figured as extending down into northern Georgia, two of which turn toward the west, the more northerly of these terminating on the Ohio River just east of the Tennessee, and the other forming the divide between the Tennessee and the headwaters of the Tombigbee River. This last feature was, however, dropped out of the second issue, published in 1817.

The classification of the geological formations as adopted by Maclure in the later issue and as given below, was naturally largely Wernerian:

CLASS I. *Primitive rocks.*

(Sienna brown.)

(1) Granite, (2) Gneiss, (3) Mica slate, (4) Clay slate, (5) Primitive limestone, (6) Primitive trap, (7) Serpentine, (8) Porphyry, (9) Sienite, (10) Topaz-rock, (11) Quartz-rock, (12) Primitive flinty slate, (13) Primitive gypsum, (14) White stone.

CLASS II. *Transition rocks.*

(Carmine.)

(1) Transition limestone, (2) Transition trap, (3) Graywacke, (4) Transition flinty slate, (5) Transition gypsum.

CLASS III. *Floetz or secondary rocks.*

(Light blue.)

(1) (*dark blue*) Old red sandstone, or First sandstone formation, (2) First or oldest Floetz-limestone, (3) First or oldest Floetz gypsum, (4) Second or variegated sandstone, (5) Second Floetz gypsum, (6) Second Floetz limestone, (7) Third Floetz sandstone, (8) Rocksalt formation, (9) Chalk formation, (10) Floetz trap formation, (11) Independent coal formation, (12) Newest Floetz trap formation.

CLASS IV. *Alluvial rocks.*

(Yellow.)

(1) Peat, (2) Sand and gravel, (3) Loam, (4) Bog iron ore, (5) Nagel-fluh, (6) Calc tuff, (7) Calc sinter.

His alluvial class, it will be observed, occupied that portion of the Atlantic border beginning with Long Island and extending southward and westward to the western Louisiana line, comprising the beds now mapped by the U. S. Geological Survey as in part Cretaceous, but mainly Tertiary and Quaternary, and forming what is known, from a physiographic standpoint, as the Coastal Plain. The materials were described as mainly sands and clays, with considerable beds of shell deposits, and in New Jersey a greenish-blue marl (the Cretaceous glauconitic marls of recent workers), used as a manure. There were also noted deposits of iron ore and ochre. His Primitive Class was essentially the area mapped as Archean on the latest U. S. Geological Survey maps; the Transition, the narrow belt of sedimentaries along the Appalachian range including the various horizons from Algonkian to Carboniferous; and the Secondary class, all that area to the west now known to be occupied mainly by Carboniferous and Silurian rocks with smaller areas of Algonkian and Cambrian. The red-brown sandstones (Triassic) of the Eastern States were classed as Floetz or Secondary and called Old Red Sandstone. This sandstone he however separated by a deeper blue in the 1818 issue from the secondary rocks on the western side of the range, because of its having a slight dip and agreeing, in the absence of organic remains and its relative position on the sides of many mountain ranges, with his Transition rocks. To the Transition beds he evidently referred all the crystalline limestones and dolomites (marbles) of western New England and the Southern States, together with quartzites and graywackes. The roofing slates, now regarded as of Cambrian and Silurian ages, he classed as secondary. The line between the Primitive and Transition may "perhaps be marked by the presence or absence of organic remains, or of aggregates of rounded particles the result of former decomposition, in part, by the more or less crystalline texture and its approach toward deposition."

To the northwest of the Transition belt lies an immense area of secondary rocks, comprising, as above noted, the horizontal limestones and slates skirting Lake Champlain about Ticonderoga and Crown Point. There are also "immense beds of secondary limestones, of all shades from a light blue to black, intercepted in some places by extensive tracts of sandstone and other secondary aggregates," which "appear to constitute the foundation of this formation, on which reposes the great and valuable coal formation," which "extends from the headwaters of the Ohio in Pennsylvania, with some interruption, all the way to the waters of the Tombigbee." He noted that along the southeast boundaries of this formation, as on the fork of the Holston in Virginia and in Greene County and the Pigeon River region of Tennessee, gypsum, salt licks, and salt springs had been discovered. In his first map this is indicated by a line of green extending northeast and southwest entirely across the State. In the second he continues it northeast to New York. The continuation of these as far north as Lake Oneida, in New York State, led him to the conclusion, since abundantly verified, that "we may hope one day to find an abundance of those two most useful substances (salt and gypsum), which are generally found mixed or near each other in all countries that have hitherto been carefully examined." He called attention to the presence of iron pyrites in the coal and limestone, of iron ores consisting principally of brown sparry and clay iron stone, and of galena in the Mississippi valley. On the Great Kanawha, near the mouth of Elk River, he noted the presence of "a large mass of black (I suppose vegetable) earth, so soft as to be penetrated by a pole 10 or 12 feet deep. Out of the hole so made frequently issues a stream of hydrogen gas, which will burn some time;" and he queried "if a careful examination of this place would not throw some light on the formation of coal and other combustible substances found in such abundance in this formation." The occurrence of large detached masses of granite over an area from Harmony, in Indiana, to Erie, New York, and thence to Fort Ann, in some cases at least 200 miles from any known outcrops, was noted, but no suggestion made relative to their probable means of transportation.

In this same year S. Godon published in the Memoirs of the American Academy of Arts and Sciences a paper of twenty-seven pages on Mineralogical Observations made in the environs of Boston in 1807 and 1808.

Godon's Mineralogical Observations, 1809.

As customary at that time, rocks and minerals were bunched together quite indiscriminately. He divided his minerals into two general groups, (1) Simple minerals and (2) Aggregate minerals. The simple minerals were then divided into Acidiferous substances (under which was placed carbonate of lime!), Earthy substances, Combustible substances, and Metallic substances. The aggregate minerals were classed under Primordial soil and Alluvial deposits. Under the first mentioned (Primordial soil) were placed all the primary and consolidated sedimentary rocks of the region. The nomenclature adopted, though somewhat cumbersome and awkward, was not more so than others since devised, the name of any rock being formed by adding the termination *oid* to that of the most characteristic mineral. Thus *amphiboloid*, *feldsparoid*, *argilloid* were the names of rocks in which amphibole, feldspar, or clay formed the chief constituent. The rhyolites (quartz porphyries and felsites) of the region were classed as simple petrosilex and compound petrosilex and the Dorchester conglomerate as wacke.

The paper offers a striking evidence of the lack of knowledge of the composition of rocks and of chemical methods at that date. Thus an attempt was made at analyzing the "argilloid" by reducing 100 parts to a "subtile" powder and mixing it with an equal part of concentrated sulphuric acid. After standing fifteen days the solid portion remaining was removed from the solution (method not stated), washed, and weighed, whereby it was found that 85 per cent remained. The solution was allowed to evaporate to dryness, and from the precipitated sulphate of lime thus obtained it was calculated that 5.5 parts out of the 15 parts soluble were of lime. Alumina and iron were determined by precipitation by ammonia—6.75 parts obtained. The liquid remaining from the alumina-iron filtrate was then dried and heated till the ammonia was driven off, the substance left dissolved in water and allowed to crystallize, producing an admixture of "well characterized sulphate of potash and sulphate of soda." "This analysis," while confessedly not of great accuracy, he wrote, "is sufficient to establish the important fact of the existence of potash and soda as elements in some rocks in this part of the world." Truly an important discovery!

In the same memoirs and this same year Prof. Parker Cleaveland, of Bowdoin College, perhaps all unintentionally, started the controversy relative to Glacial and post-Glacial uplift and depression by announcing the finding of fossil shells belonging to genera still living in deposits of sand and clay well above sea level at Brunswick, Maine.

In January, 1810, there was established by Prof. Archibald Bruce the American Mineralogical Journal, the first American publication designed primarily for geologists and mineralogists. The life of this journal was, however, short, the last issue bearing the date of 1814, and the whole number comprising but 270 pages.

Bruce's American Mineralogical Journal, 1810.

The first paper was by Samuel L. Mitchill, professor of natural history and botany in the University of the State of New York. This consisted of an annotated catalogue accompanying a suite of mineral specimens made during a tour to Niagara in 1809.

Among the other papers which followed mention may be made of one by Colonel Gibbs on the Iron Ores of Franconia, New Hampshire; by Benjamin Silliman on the Lead Mines near Northampton, Massachusetts; by James Catbush on the Blue Earth of New Jersey, and by W. Meade on Elastic Marble, a "fossil of rare occurrence" found near Pittsfield, Massachusetts.

FIG. 1.—Archibald Bruce.

The more important strictly geological papers were by Dr. Samuel Akerly and included a geological account of Dutchess County in New York, one on the improbability of finding coal on Long Island or in the vicinity of New York, and one on the geology and mineralogy of the island of New York. Akerly described the highlands of Dutchess County as consisting of granitic rocks, and the whole country north of the highlands as underlaid with primitive slate, most of the hills being composed of limestone. New York Island was described as underlaid throughout its northern part by primitive rocks, granite, and limestone; the southern part, upon which the then existing city was built, as composed of an alluvion of sand, stone, and rocks. This he regarded as a recent deposit "subsequent to the creation and even the deluge." The manner in which this alluvial material was deposited he described as follows:

After the waters of the Deluge had retired from this continent, they left a vast chain of lakes, some of which are still confined within their rocky barriers; others have since broken their bounds and united with the ocean. The highlands of New York was the southern boundary of a huge collection of water, which was confined on the west by the Shawangunk and Katts-kill mountains. The hills on the east of the Hudson confined it there. When the hills were cleft and the mountains torn asunder, the water found vent and overflowed the country to the south. It was then that the channel of the Hudson was formed, and its stream has never since ceased to flow. The earth, sand, stones, and rocks brought down by this torrent were deposited in various places, as on this island, Long Island, Staten Island, and the Jerseys. This opinion is mostly hypothetical, because unsupported by a sufficient number of facts, but that it is probable may be judged by what follows. (See Mitchill's views on p. 231.)

In the same journal Samuel Brown, of Lexington, Kentucky, gave a description of a cave on Crooked Creek, with remarks and observations on niter and gunpowder; Robert Gilmore, a descriptive catalogue of minerals occurring in the vicinity of Baltimore; while S. L. Mitchill proposed an amendment to Maclure's chart of the United States so far as it related to the character of the north side of Long Island, which he showed to be alluvial and not primitive, as stated, and Benjamin Silliman described the plain of New Haven as wholly alluvial and of very recent origin. This paper is evidently a partial reprint of one offered before the Connecticut Academy of Sciences in 1810 and referred to elsewhere (p. 216).

A paper by J. Corre de Serra, the Portuguese minister then residing in Philadelphia, read before the American Philosophical Society in 1815, and published in their Transactions in 1818, is of interest as showing the condition of knowledge relative to so commonplace a phenomenon as that of rock weathering and formation of soils. His paper was entitled Observations and Conjectures on the Formation and Nature of the Soil in Kentucky. He regarded this soil as the product "of the decomposition of an immense deposit of vegetables which the ocean had left uncovered by any other deposition."

F. W. Gilmer's ideas on the Natural Bridge.

It may be remembered that Jefferson, in his notes on the State of Virginia, had described in considerable detail and very eloquently the now well-known Natural Bridge of Rockbridge County, which he regarded as spanning a gigantic fissure, the result of some great convulsion. In the Transactions of the American Philosophical Society for 1816 (1818) Francis William Gilmer had a paper on the same subject, illustrated by a full-page plate. The bridge was described in detail and its formation ascribed, not to a sudden convulsion, as argued by Jefferson, or to any extraordinarily sudden deviation from the ordinary laws of nature, but to the "very slow operation of causes which have always and must ever continue to act in the same manner." This cause he rightly considered to be the solvent action of meteoric waters on limestone. In this respect Gilmer, although scarcely known to geological science, was vastly in advance of the workers of his day.

Views of the Rev. E. Cornelius, 1819.

Three years later the Rev. Elias Cornelius, a man of education and culture, but whose professional training seems to have quite unfitted him for the work of a geologist, also discussed the subject in a paper in the American Journal of Science, giving the results of his observations on the geology of parts of Virginia, Tennessee, and the Alabama and Mississippi territories. He dissented from any of the views thus far expressed, and in the sublimity of his faith could see no good reason, or in his own words, no "difficulty even in supposing it (i. e., the bridge) to have proceeded from the hand of the Almighty as it is."

Next to Maclure's Observations on the Geology of North America, undoubtedly the most important of the early publications was Parker Cleaveland's Elementary Treatise on Mineralogy and Geology, a work of upward of six hundred pages, with five plates of crystal drawings and a colored geological map.

Cleaveland's Treatise on Mineralogy and Geology, 1816.

For most of the geological observations and for the map Cleaveland was indebted to Maclure and to written communications from H. H. Hayden. The principal variation from Maclure's map lay in the adoption of the suggestion of S. L. Mitchill regarding the extension of the alluvial deposits on Long Island. It further differed from that published by Maclure in 1817 in that a large portion of southern and western Maine was colored as occupied by transition rocks, this area having been left blank by Maclure.

The classification adopted in the work was largely chemical, the minerals being divided into (1) classes, (2) orders, (3) genera, and (4) species, his definition of species being "a collection of materials which are composed of the same ingredients, combined in the same proportions."

In the tabular view given, all known minerals were grouped under four classes, as follows: Class 1, substances not metallic, composed entirely or in part of an acid; class 2, earthy compounds or stones; class 3, combustibles, and class 4, ores. As was the case with all writers of that day, basalt and several other compact rocks of indistinct mineralogical nature were classed as minerals. Thus is found under class 2, species 15, *porcellanite;* species 16, *silicon slate;* species 32, *emerald*, and species 34, *basalt*. This last was described as never crystallized but occurring "in large amorphous masses, but also under a columnar, tabular, or globular form" and passing insensibly into "greenstone, wacke, and perhaps clinkstone."

Not only was the mineralogical nature of basalt little understood, but even its relationship to volcanic rocks as well. It was described as sometimes found in countries decidedly volcanic, but seldom near the craters of still active volcanoes; "on the contrary, it appears at the foot of volcanic mountains and sometimes almost surrounds them." Some of the most noted localities mentioned are the Giant's Causeway, island of Staffa, the Erzgebirge, Auvergne, etc. Its occurrence in the United States was regarded as doubtful, though he noted its reported occurrence on the Stony (Rocky) Mountains. It was regarded as of both igneous and aqueous origin.

Anthracite, which forms species 6 under class 3, combustibles, was described as "strongly resembling *coal*, from which, however, it materially differs." It was said to occur in primitive or transitional rocks, though sometimes connected with secondary rocks. Obviously, therefore, it is stated, it has not, at least in many cases, resulted from the decomposition of vegetable matter.

Pages 586 to 636 of Cleaveland's first edition included an introduction to the study of geology. Some of the statements here made are of interest: "Most of those extensive masses of strata," he wrote, "with which geology is concerned are compound minerals, or aggregates, composed of two or more simple minerals mingled in various proportions and denominated rocks." While thus a division into species and genera may be possible with minerals, with rocks the case is quite different. "It is obvious that they can not admit of distinctions which are strictly specific." This observation holds good to the present day. His remarks on the position of the beds of rocks were no less interesting:

When primitive rocks are stratified the strata are seldom horizontal. On the contrary, they are often highly inclined and sometimes nearly or quite vertical. But whether these strata were originally inclined or whether, subsequent to their formation, they have been changed from a horizontal to an inclined position by the action of some powerful cause, is a question on which the most distinguished geologists are divided in opinion.

Again:

It is further evident that the higher the level at which any rock appears at the surface of the earth, the older is the rock; for it so declines as to pass under those rocks which appear at a lower level. The only exception to this general fact appears in those horizontal strata of secondary rocks which sometimes rest on the summits of high mountains.

The theory of the earth adopted by Cleaveland is apparently that of Cuvier. In his discussion of the origin of rocks and geological systems he was for the most part a follower of Werner, though he recognized some of the difficulties attendant upon the complete adoption of the Neptunian theory. "Though its general outlines may be correct, we are yet unable to give its details. It seems, however, to be rather encumbered with difficulties than absolutely confronted by existing facts." His views regarding volcanoes were largely a reflection of those advocated by his European contemporaries, and need but brief allusion.

Many parts of the external crust of the earth are subject to the action of subterraneous fire. In some cases these fires are comparatively mild and produce no important effects, excepting the destruction of the combustibles which feed them, and are nothing more than coal mines in a state of combustion. But in other cases these subterraneous fires rage with resistless impetuosity.

Cleaveland was a graduate of Harvard in the class of 1799, and was in 1805 appointed to the professorship of mathematics, natural philosophy, chemistry, and mineralogy in Bowdoin College, Brunswick, Maine. He is described by his biographer (the elder Silliman) as a man of great natural ardor and activity, with a reputation for zeal, industry, and learning. To these statements certainly no one will take exception, when the period and magnitude of his work and manifold character of his professional

Sketch of Cleaveland.

PARKER CLEAVELAND.
Professor of Chemistry and Mineralogy, Bowdoin College.

duties are taken into consideration. It must be remembered that his was the first attempt made in America at a systematic treatise on mineralogy. (Shepard's came sixteen and Dana's twenty-one years later.) The only available foreign works were those of Jameson, Kirwan, Werner, and Brongniart; moreover, there were in America few, if any, important mineral cabinets, those of B. D. Perkins, Archibald Bruce, and Col. George Gibbs alone being worthy of mention. The work, we are told, was received with great favor, two editions being issued, the second in two volumes bearing date of 1822. A third was called for but never prepared, owing to the failing health of the author.[a]

An interesting side light is thrown by one of the reviewers of the first edition upon the condition of the science at that time. Thus he wrote of Hauy's "curious discoveries regarding the six primitive figures or solids which form the base of all crystals," and called it "the most singular and acute discovery of our age," though "there is a difference of opinion among mineralogists as to the practical use of crystallography in the discrimination of minerals." The same reviewer naively remarked: "In this age of bookmaking it is no small negative praise if an author be acquitted of unnecessarily adding to the onerous mass of books."[b]

Second Edition of Maclure's Observations, 1817.

Not satisfied with his first edition, which, according to Marcou, was published during the author's absence in Europe, Maclure immediately set about obtaining the necessary information for a revision, and in 1817, after eight years of hard work, presented the amended memoir, which was republished in the transactions of the Philosophical Society and also in the form of a separate volume of 127 pages, bearing the same date. The second issue differed considerably from the first, the most conspicuous features being the delineation of the mountain ranges and the correction of many minor details regarding the distribution of various geological formations.

On Plate 2 of this issue he gave five sections across the United States from the Atlantic, through the Appalachian regions and the secondary rocks of the Mississippi, which were colored to correspond with the

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[a] In a letter dated Madrid, August 20, 1822, Maclure writes to Cleaveland as follows: "I felicitate you on a second edition of your mineralogy being so soon necessary. The mineralogical professor here, Dn. Donato Garcia, has the intention of translating your work into Spanish as the best elementary book yet known." As to whether or not this intention was carried out, the present writer has no information.

[b] The second American work on mineralogy by one who could with propriety be called a mineralogist and original worker was Prof. C. U. Shepard's Treatise on Mineralogy, Shepard being at that time twenty-eight years of age and an assistant to Professor Silliman at New Haven. The work, which was founded on that of the well-known Austrian mineralogist, Mohs, appeared in the form of a small octavo volume of 256 pages. In 1835 a second part in two volumes of 630 pages appeared. Being purely mineralogical in its nature, but passing note can be made of it here. A second edition was issued in 1844.

scheme in the map. (See Plate 5.) The first section extended from Camden in Penobscot Bay, Maine, to Oxboro, near Kingston, on Lake Ontario; the second from Plymouth, Massachusetts, to Cayuga Lake, New York; the third from Egg Harbor, New Jersey, to Pittsburg, Pennsylvania; the fourth from Cape Henry, Virginia, to Arlington, in the same State, and the fifth from Cape Fear, North Carolina, to Warm Springs, in the same State. The poverty of information at that time relative to the Rocky Mountain region is shown in the statement that "the tops of the Stony Mountains are covered to a considerable extent with perpetual snows and pendent glaciers."

As was the case with a majority of the earlier surveys and geological text-books, considerable attention was given to the relation of the science to agriculture, and the two closing chapters of the second issue were given up to Hints on the Decomposition of Rock, with an Inquiry into the Probable Effects they may Produce on the Nature and Fertility of Soils. The kinds of soils resulting from the decomposition of various rocks were discussed with particular attention to their physical nature, but while occasional references were made to their content of lime, the alkalies, and other constituents, no chemical analyses were given, nor was their desirability apparently appreciated.

It does not seem to have been realized, however, that throughout the entire glaciated area as now known there may be little connection between the soils and the rocks immediately underlying them.

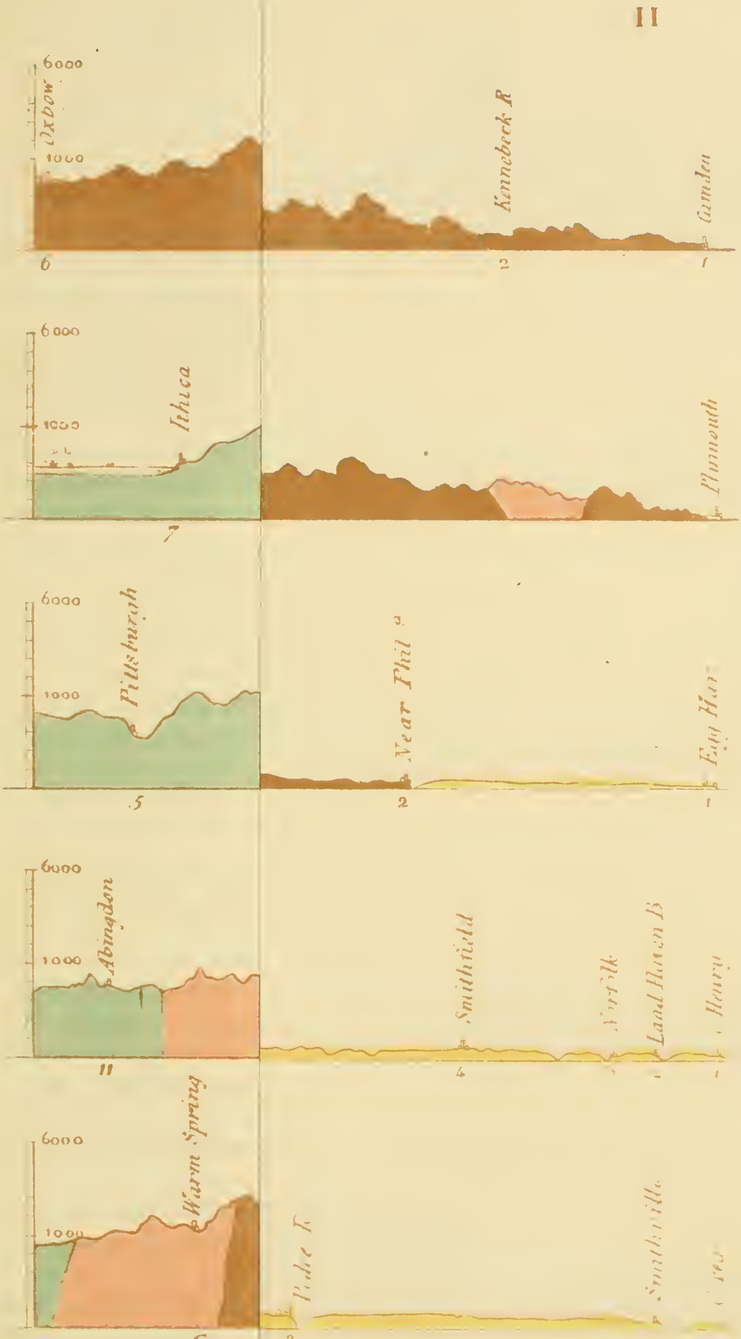
During 1818, as already noted, there was founded the American Journal of Science, or, as it was familiarly called, Silliman's Journal, the first volume bearing on the title-page the date 1819. It is notable as being the first American journal to be given up largely to geological subjects, although other sciences were by no means debarred. In fact, as noted in his plan of the work, the Journal was intended to embrace the circle of the physical sciences and their application to the arts and to every useful purpose.

The American Journal of Science, 1818.

From its earliest inception geological notes and papers occupied a prominent place in its pages, and a perusal of the numbers from the date of issue down to the present time will, alone, afford a fair idea of the gradual progress of American geology. I shall note in the following pages many articles taken from the Journal, particularly the earlier numbers, as serving best to illustrate the condition of the science at the time of their issue.

Among the earliest publications on the geology and mineralogy of New England mention must be made of J. F. and S. L. Dana's Outlines of the Mineralogy and Geology of Boston and Vicinity, which bears the date of 1818, and which is further noteworthy for containing a geological map of the area indicated, being antedated only a year by Edward Hitchcock's geological map of a part of Massachusetts on the Connecticut River

Dana's Geology and Mineralogy of Boston, 1818.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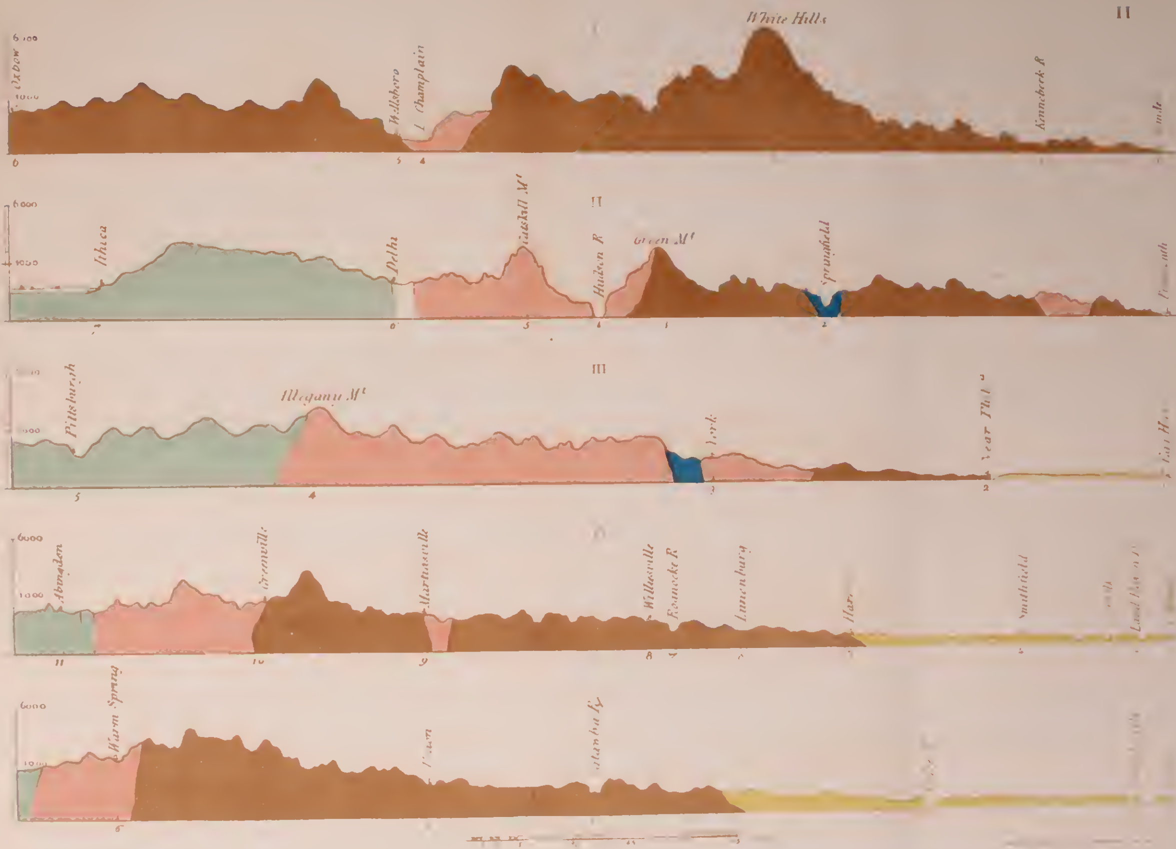


MACLURE'S SECTIONS ACROSS THE APPALACHIANS.

Copy of original in Transactions of American Philosophical Society, 1818.

and the various reprints of Maclure's. The classification adopted was that of Werner, and hence, of course, purely lithological. The various rocks enumerated and colored on the map were: I. The Primitive, including granite, argillite, primitive trap, porphyry, and syenite; II. Transition, including amygdaloid and graywacke; and III. Alluvial, including sand, pebbles, clay, and peat. No granite was, however, recorded as in place, the granite of Quincy and the areas west of north of Marblehead being colored as syenite. The argillite was regarded as the oldest rock occurring in the vicinity, and was represented as forming gently undulating eminences in Charlestown, Watertown, Chelsea, and Quincy. Greenstone, or primitive trap, was represented as occupying all of the Marblehead-Salem areas and large areas to the west, including Stoneham and Lexington. Porphyry, "a compound rock having a compact basis, in which are embedded crystals or grains of other minerals of contemporaneous formation," and which passes into both syenite and petrosilex, they found in Malden, Lynn, and Chelsea, while the large area beginning at the shore east and north of Lynn and extending southwestward as far as Malden, was colored as *petrosilex*. A wide strip, extending from just west of the Charles River to the coast, including Brookline, Roxbury, and Dorchester, was colored as *graywacke*, this being, of course, the conglomerate of later writers. On the northern and western edges of this are narrow belts colored as *amygdaloid*, the same being the rock later shown by Benton to be melaphyr, or ancient basaltic lava flow.

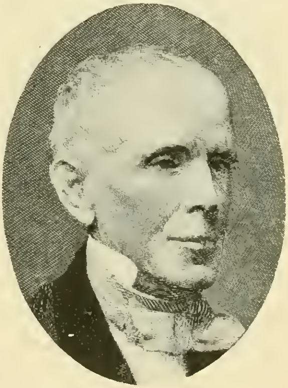


FIG. 2.—Samuel Luther Dana.

The minerals as described were divided into Class I. Earthy fossils; Class II. Saline fossils; Class III. Inflammable substances; and Class IV. Metallick fossils. Under Class I were included the phosphates and carbonates of lime, quartz, such silicates as mica, shorl, feldspar, garnet, epidote, the amphiboles, etc., and such compound substances as petrosilex, basalt, wacke, schaalstone, argillaceous slate, and clay. The second class, Saline Fossils, included but a single species, sulphate of iron. Class III included hydrogen gas and peat, and Class IV sulphides and chlorides of copper, sulphide, oxide, and carbonate of iron, sulphide of lead, and oxide of manganese. The classes were subdivided into orders and the orders into genera, species, subspecies, and varieties. Thus novaculite was considered a subspecies of argillaceous slate, a species under Order II, Nonacidiferous substances of Class I, Earthy fossils. Altogether some 21 species of Earthy fossils were recognized, 1 of Saline fossils, 2 of Inflammable substances, and 8 of Metallick fossils. These were all described in detail, their physical characters and conduct before the blowpipe, and their place of occurrence. Perhaps no better means of showing the condition of the science at that time can be found than by reproducing here a page of the original descriptive matter under Class I, Order II.

SPECIES VII—WACKE.

Wacke, *Cleaveland*, p. 287. Wacce, *Jameson*, vol. 1, p. 376. Wacken, *Kirwan*, vol. 1, p. 223. Wakke, *Aikin*, p. 254.

External characters.

Its colours are grey and purple. Of grey, it occurs blackish grey and greenish grey; of purple, lavender purple. The colours vary much in their intensity.

It is dull.

It is amorphous and cellular.

It exhales a strong argillaceous odour when breathed upon.

It adheres to the tongue.

Its streak is greyish white, with a reddish purple tinge in some parts, and is dull.

It is moderately hard, passing to soft.

The fracture is from fine grained uneven to earthy; some specimens show a slightly slaty structure.

It is brittle.

It is easily frangible.

The fragments are indeterminately angular and not particularly sharp edged.

Its specifick gravity is about 2.88.

Chymical characters.

Before the blowpipe it melts into an opaque, semi-vitreous mass which appears porous when broken.

Geological situation and localities.

It occurs in beds in Petrosilex at Milton, and forms the basis of Amygdaloid at Brighton, Hingham, Newton, &c., and it is found also in rounded fragments at Needham, Newton, Brighton, &c.

Remarks.

This mineral sometimes much resembles ferruginous clay, and is intermediate between Clay and Basalt. It is very liable to decomposition, and when it forms the basis of Amygdaloid, by undergoing this change, it leaves the imbedded minerals projecting, or they fall out and leave the Wacke cellular. [a]

Mitchill on the Geology of North America, 1818.

In 1818 there was published by Kirk and Mercein in New York Robert Jameson's translation of Cuvier's celebrated essay on the Theory of the Earth, and with it S. L. Mitchill's Observations on the Geology of North America.[b] It is the Observations alone that need now receive our attention, and this with particular reference only to what is said regarding the origin of the drift. Mitchill was one of the most prominent

[a] This work was the subject of a scathing review in the Analectic Magazine, XIII, 1819, where the writers were accused of having borrowed at least three-fourths of their material "for the mere purpose of eking out the matter to the proper size of a *justum volumen*—of borrowing the most elementary ideas of the most common authors." * * * "A student who has read either Cleaveland, Jameson, or Aikin, will find not a sentence that is new in at least nine-tenths of the book; which is in fact a disgraceful example of literary book-making, as it respects both the matter and the manner."

[b] There was manifested, particularly by the publishing houses of Philadelphia, an

scientific men of his day, had read and traveled extensively, and it may be safe to assume that the views held by him were supposed to rest upon a good foundation, though they were not wholly accepted, as is mentioned later.

It was Mitchill's idea that the Great Lakes were the shrunken representatives of great internal seas of salt water, which ultimately broke through their barriers, the saline lakes becoming gradually freshened by a constant influx of fresh water. The remains of the barriers which held back for a time this inland sea he thought to be still evident. One of them, he wrote, seemed to have circumscribed to a certain degree the waters of the original Lake Ontario and to be still traceable as a mountainous ridge beyond the St. Lawrence in upper Canada, northeast of Kingston, passing thence into New York, where it formed the divide between the present lake and the St. Lawrence, and, continuing to the north end of Lake George, apparently crossed the Hudson above Hadley Falls. Thence he believed it to run toward the eastern sources of the Susquehanna, along the Cookwago and Papachton branches of the Delaware, crossing the last named a little north of Easton (Delaware Watergap), the Lehigh north of Heidelburg (Lehigh Gap), and the Schuylkill northwest of Hamburg in Pennsylvania. Continuing thence along to the north of Harrisburg, across the Susquehanna, in a southwesterly direction until it entered Maryland, and passed the Potomac at Harpers Ferry into Virginia, where it became confounded with the Allegheny Mountains. Thence gradually disappearing, traces of it appeared to the westward, as at Cumberland Gap in Tennessee and the mountains west of Cape Girardeau beyond the Mississippi.

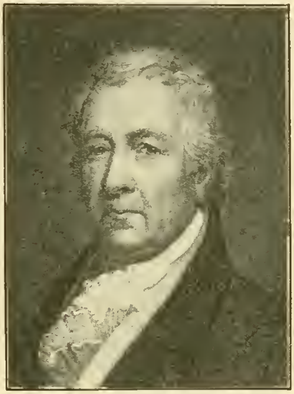


FIG. 3.—Samuel Latham Mitchill.

It is evident that for a good part of its course, as traced, this barrier was but the Blue Ridge, while in eastern New York it was comprised mainly of the Catskills and Adirondacks.

To appreciate Mitchill's view, then, we have to imagine this now broken and gapped ridge as continuous throughout its whole extent, forming a vast dam holding back the waters of several salt inland seas

early tendency to reprint many of the English works on geology and mineralogy. This finds its most important illustration, from the present standpoint, in the reprinting of Frederick Accums's A Practical Essay on the Analysis of Minerals (Philadelphia, 1809); Cuvier's Essay, as noted above; Bakewell's An Introduction to Geology (New Haven, 1829); Cuvier's A Discourse on the Evolution of the Surface of the Globe (Philadelphia, 1831); and De la Beche's A Geological Manual (Philadelphia, 1832), etc.

to the northward, while the region to the southward was dry land. A time came, however, when the dams at various points proved too frail and gave way, the pent-up waters rushing through and carrying devastation with them like the waters from cloud-bursts or bursting reservoirs of to-day, but on a thousandfold larger scale.

One breach was conceived to have been at the northeastern extremity of Lake Ontario. The Thousand Isles, to Mitchill's mind, "bear witness to the mighty rush of waters which thus prostrated the opposing

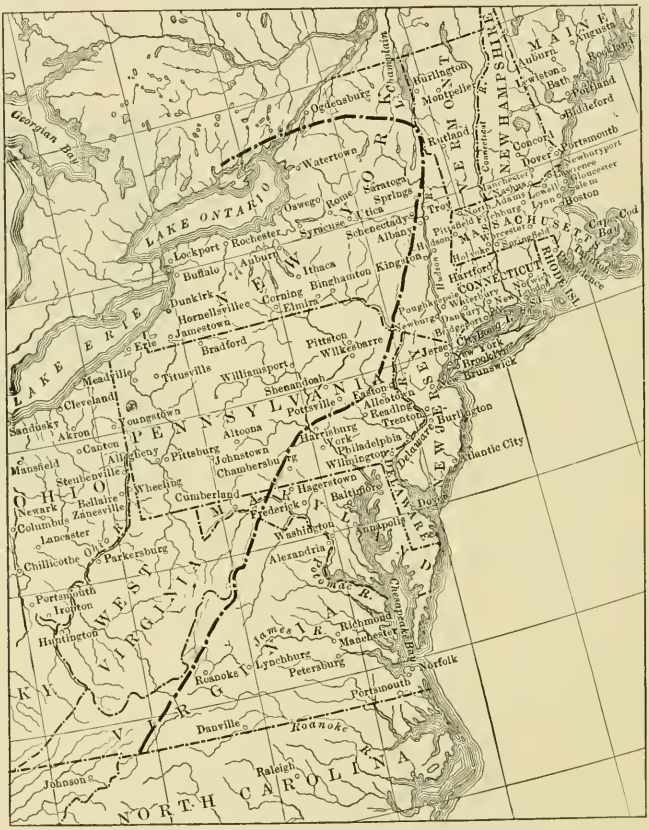


FIG. 4.—Map to illustrate Mitchill's theory of barriers.

mound and left them as scattered monuments of the ruin." "By this operation the water must have subsided about 160 feet," or to its present level.

All the country on both the Canadian and Fredonian sides must have been drained and left bare * * * exposing to view the waterworn pebbles, the works of marine animals, their solid parts buried in the soil, their relicks bedded in the rocks, and the whole exhibition of organic remains formed in the bottom of such a sea as that was.

Great masses of primitive rocks from the demolished mound or dam and vast quantities of sand, mud, and gravel were carried down the stream to form the curious mixture of primitive with alluvial materials in regions below.

A second breach was conceived to have been at the northern extremity of Lake George, whereby the lake was diminished to about its present size. A third was at Hadley Falls; a fourth at the upper falls of the Mohawk; a fifth was made by the pent-up waters of the Delaware above Easton, Pennsylvania; a sixth by the Lehigh to the northwest of Bethlehem; a seventh by the Schuylkill; an eighth by the Susquehanna, and a ninth by the Potomac cutting its way through the Blue Ridge at Harpers Ferry. A second series of lakes and dams he conceived as having existed outside, i. e., to the southward of those above mentioned. To the bursting of these he attributed many of the minor features of the present landscape.

The work contains little in the way of systematic geology aside from the speculations above mentioned, though there are disconnected references to and descriptions of fossil remains and rocks found in various parts of the country. He, however, called attention to the possibility of the Great Lakes having formerly drained into the Mississippi, the gradual retreat of the falls of Niagara, and the formation of the gorge through the undermining of the harder surface limestone, facts which seem to have been very early recognized.

Edward Hitchcock's First Geological Paper, 1818.

This same year witnessed the first appearance in geological science of Edward Hitchcock, then a young theological student of twenty-five, but who was destined to be one of the most prominent figures of his time. Hitchcock came first into notice in 1815 through some astronomical observations and corrections furnished Blunt's Nautical Almanac. His inclination, however, early took a geological turn, and throughout a prolonged period of activity, first as a clergyman and later as professor, president, and again professor in Amherst College, he kept himself ever prominently to the front.

The first State geological survey carried to completion, that of Massachusetts, 1830–1833, was primarily his conception and executed almost wholly through his efforts. He became, however, most widely known and is best remembered through his work on the footprints found in the Triassic sandstones of the Connecticut Valley and his studies of the drift phenomena, in both of which he was a pioneer. Indeed, if one may be allowed to speak facetiously of so cultured and dignified a gentleman, he was America's first "superficial geologist," and a perusal of his papers alone will give a very fair idea of the development of the glacial hypothesis in America.

The paper to which allusion is made above, Some Remarks on the Geology and Mineralogy of a Section of Massachusetts on the Connecticut River, with a Part of New Hampshire and Vermont, was published in the first volume, 1818, of the American Journal of Science. It is noteworthy on account of a geological map of the region, colored by hand, and a transverse section of the rock strata from Hoosac Mountain to 11 miles east of the Connecticut River. The rocks were classed as primitive, secondary, and alluvial, the older crystallines and the argillites being considered as primitive, while the traps and sandstones were put down as secondary.

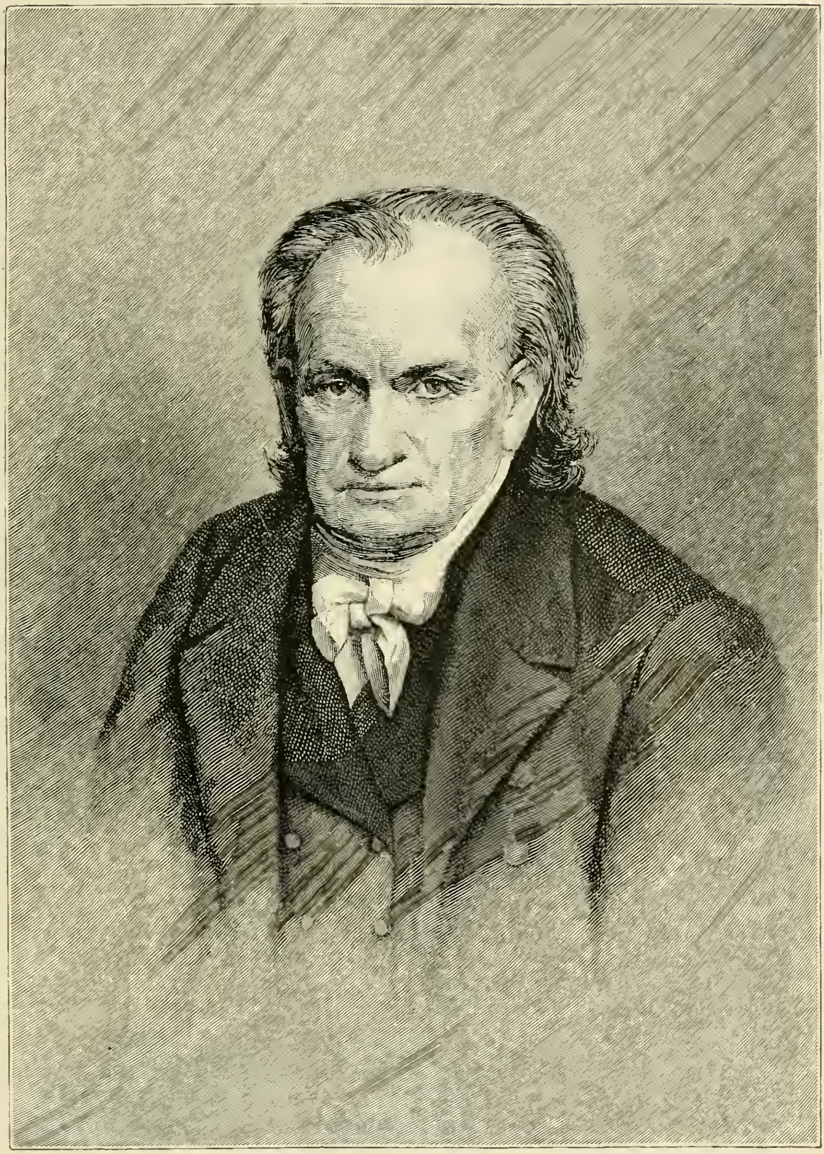
The year 1818 was rendered notable also by the appearance in the geological arena of Amos Eaton, a man who, like Hitchcock, was destined to achieve a national reputation, but whose mental characteristics were as unlike Hitchcock's as was possible among men in the same calling. His first geological paper occupied three pages of the American Journal of Science for the year under discussion. His first noteworthy publication was the Index to the Geology of the Northern States, which appeared in the form of a text-book for the geological classes at Williams College that same year. Eaton is described as a man of great force, untiring energy, and was one of the most interesting men of his day. In 1816, at the age of forty, he abandoned the practice of law and went to New Haven to attend Silliman's lectures on mineralogy and geology. Subsequently he traveled many thousand miles on foot, throughout New England and New York, delivering in the principal towns short courses of lectures on natural history. In March, 1817, having received an invitation to aid in the introduction of the natural sciences in Williams College, his alma mater, he delivered a course of lectures in Williamstown. Such was the zeal at this institution, he wrote, that "an uncontrollable enthusiasm for natural history took possession of every mind, and other departments of learning were for a time crowded out of the college." In April, 1818, on invitation of Governor De Witt Clinton, he delivered in Albany, before the members of the State legislature, a course of lectures on natural history. Here was undoubtedly the beginning of the work which resulted in the establishment of the State survey.

Eaton's Index, 1818.

In the "Index" mentioned above (which has been pronounced "the first attempt at an arrangement of the geological strata of North America") the views expressed were naturally largely tinged with Wernerism. They are reviewed in detail here, even when almost exact equivalents, on account of their local application.

Eaton divided the rocks of the earth's crust into five classes: First, Primitive; second, Transition; third, Secondary; fourth, Superincumbent; and, fifth, Alluvial; the body of the work, occupying pages 15 to 41, inclusive, being given up to their description and geographical distribution.

Under the head of Primitive rocks he included granite, granular limestone and quartz, gneiss, mica-slate, soapstone rocks, calcareous and granular quartz, and syenite. These were regarded as barren of fossil remains and the oldest rocks to which human research had extended.



AMOS EATON.

Professor of Natural Science, Rensselaer Polytechnic Institute.

The Transition class included metalliferous limestone, argillaceous and siliceous slate, graywacke slate, and rubblestone.

The Secondary class included red sandstone, breccia, compact limestone, gypsum, and rocksalt; the Superincumbent class, basalt, greenstone, trap, and amygdaloid, and the Alluvial class, gravel, sand, clay, and loam.

Illustrative of his ideas concerning the position of these rocks, a geological transverse section was given, extending from Boston on the east to the Catskill Mountains on the west. From a perusal of this section and the accompanying text many interesting and, to us, striking conclusions are drawn. For instance, in discussing the position of the gneiss of the Primitive series as it occurs between Dalton and Pittsfield, Vermont, he wrote: "It sinks laterally under the mica-slate to the west, and probably does not rise again until it reaches the continent of Asia." The soapstones and serpentines, now known to be altered eruptive rock, were regarded by him as forming one of the concentric coats of mechanically deposited materials, and, as with syenite and granite, their possible eruptive origin not dreamed of.

In his Transition class he would include the marbles of western Vermont, now considered to be of Lower Silurian and Cambrian age, and the roofing slates.

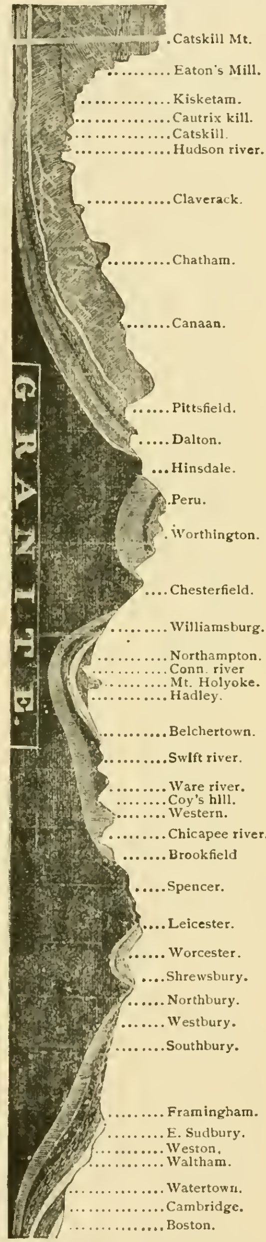


Fig. 5.—A Geological Transverse Section, extending from Catskill Mountain to the Atlantic. (By Amos Eaton.)

Successive arrangement of the strata:

1. Granite.
2. Granular limestone and quartz.
3. Gneiss.
4. Mica slate.
5. Soapstone rocks.
6. Calcareous and granular quartz.
7. Sienite.
8. Metalliferous limestone.
9. Argillaceous and siliceous slate.
10. Graywacke slate.
11. Rubblestone.
12. Red sandstone.
13. Breccia.
14. Compact limestone.
15. Gypsum.
16. Rock salt.
17. Superincumbent rocks.
18. Alluvial deposits.

In the Secondary class he included the red sandstones of the Catskills (Devonian), as well as those of the Connecticut River (Triassic). Discussing the position of the Catskill stone, he wrote: "Bakewell removed this stratum from the Secondary class (where Werner placed it) to the Transition. He says this stratum terminates the series of transition rocks containing metallic veins and the more ancient organic relics. Had Bakewell ever visited Catskill Mountain he would undoubtedly have left the red sandstone where Werner placed it; for here the true old red sandstone of Werner contains the organized remains of at least one well-known phenogamous woody plant."[a] He also stated that this sandstone contained the petrified remains of the roots of the *Kalmia latifolia*, or common laurel! The gypsum and rocksalt beds of New York and Pennsylvania, now regarded as of Salina age, he included in this Secondary class, and also the common compact limestone occurring in the western part of New York State, but not found east of the Hudson River.

In the Superincumbent class were included, as already stated, greenstone trap, amygdaloid, and basalt, which he regarded as varieties of one and the same rock. This assumption on his part is interesting in connection with the discussion of the last twenty years (since the introduction of the microscope into geology) regarding the now well-established relationship existing between basalt, melaphyr, and diabase. While these rocks were considered by him as volcanic, their exact source seemed problematic. "On the Deerfield River the greenstone sinks down in a fissure in the red sandstone. * * * Bakewell would say here were volcanoes and here the melted greenstone was thrown up through the sandstone."

In discussing his Alluvial class, he wrote:

> It is agreed by all geologists that all soils, excepting what proceeds from decomposed animal and vegetable matter, are composed of the broken fragments of disintegrated rocks. From this fact it is natural to infer that the soil of any district might be known by the rocks out of which it is formed; consequently, that rocks abounding in quartz would produce a sandy soil and those abounding in argillaceous slate a clay soil, etc. * * * This inference is certainly correct, but there is great difficulty in determining what rocks may have extended over any particular district and been entirely dissolved in former ages. Is there not good reason to believe that most of the strata now constituting Catskill Mountain * * * once extended over Massachusetts to the Atlantic Ocean?

That these strata once extended as far as Massachusetts and united to the same strata at Pittsfield and Stockbridge he regarded as beyond question, and he concluded that a mass of rock from 1,000 to 3,000 feet in thickness, from 20 to 30 miles in breadth, and perhaps 80 miles in length, had been dissolved and mostly washed down the Hudson River. Fragments of every stratum he thought were still to be found in small masses throughout the towns in the vicinity. The possibility

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[a] Concerning this Hall remarks (Geology of Fourth District, p. 6): "It is a remarkable fact that at this early period Mr. Eaton should have recognized the sandstone of the Catskill Mountains as the Old Red of Europe, which, now that we have identified its characteristic fossils, is proved to be true."

of glacial drift was of course at that time wholly unrealized, and he accounted for the masses of granite and syenite, weighing from 1 to 50 tons, which are scattered throughout the Connecticut River region, as residuary fragments from atmospheric decomposition.

What force can have brought these masses from the western hills across a deep valley 700 feet lower than their present situation? Are we not compelled to say that this valley was once filled up so as to make a gradual descent from the Chesterfield range of granite, sienite, etc., to the top of Mount Tom? Then it would be easy to conceive of their being rolled down to the top of the greenstone, where we now find them.

In this year Eaton published also his Conjectures Respecting the Formation of the Earth. In this, largely following Werner, he taught that the water now covering three-fourths of the earth's exterior was at one time thoroughly commingled with the solid materials constituting the globe in such a manner as to form a very thick paste. Such being the primary condition, the heaviest materials contained in this globular mass of mortar would soon begin slowly to settle together, the heaviest naturally at the center. Further, that such settling took place in inverse order of the specific gravities of particles, forming thus several concentric layers of metals, arranged like the coats of an onion. This settling went on until finally granite was deposited, several thousand years being regarded as necessary for the completion of all the strata. Previous to the deposition of granite, gneiss, mica-slate, and other primitive rocks, neither animals nor vegetables were conceived to exist, for no traces of them have been discovered in the rocks of these types.

As condensation went on, the water being disengaged from the inner deposits and forced gradually toward the exterior of the mass, the earth paste became more diluted, and a few zoophytes, shell animals, and cryptogamous plants were created, as was shown by the finding of their remains in the transition rocks overlying the primitive.

The continued dilution of the water by the deposition of the materials of the transition series was followed by the creation of several species of fish, and as the solution was thinner the deposits of the secondary rocks went on with considerable rapidity. During this time the red sandstone, compact limestone, and indurated marl were deposited, entombing incidentally individuals of the various plants and animals enumerated.

While this secondary formation was going on the internal heat of the earth immediately beneath the granite, by converting the water which remained in the subterranean interstices into steam, began to raise up the rocks of granite. The expansion of this steam found relief by forcing its way wherever the least resistance was presented, and as strata can be separated from each other easier than they can be broken through, the steam probably traveled laterally round the earth, separating the granite from the next stratum below. At length the force of the more highly rarefied steam became too great to be any longer confined within the coat of granite. It burst through at the weakest part and shot forth its craggy broken edges above the muddy waters which surrounded it.

Concerning the source of this heat, "whether it arose from the admixture and combustion of substances then abounding beneath the granite," or whether "it was excited by the concentric layers of metallic plates serving as a vast galvanic battery," Eaton was non-committal.

The projecting edges of granite, together with the uplifted strata of transition and secondary rocks, formed the first islands and continents of dry land. Alluvial deposits had already commenced under water, and therefore parts of the raised islands and continents were prepared for the reception and support of plants and animals of the more perfectly organized structure.

These, however, were not the continents of the present day, which were conceived then to be at the bottom of the primeval ocean, but were rather the continents occupied by antediluvians, and which are now in their turn probably at the bottom of the Indian Ocean. This land, he argued—

may have been supported by the meeting place of two vast segments of uplifted granite which contained beneath them an immense subterranean sea. Our present continent may now be supported in the same way and the meeting of the edges of segments form the granitic ridge which extends from Georgia to the Frigid Zone—that is to say, that which forms the Appalachian Mountain system.

In whatever manner the ancient world was supported, it is evident that when the wickedness of man drew down the vengeance of the Almighty, its foundations gave way and it sank to the bottom of the ocean never to be again uplifted.

Incidental to this catastrophe, he conceived there may have been formed a "vacuum wherein much water might subside;" or possibly several continents falling in contemporaneously, basins were formed—

sufficient to hold all the waters which had hitherto covered the continents of our day; or, perhaps, the pressure at the outer margins of the falling continents might force up the granite, which raised our continents out of the ocean. * * * At any rate, the fountains of the great deep were broken up, and our continents, then at the bottom of the great deep, emerged into open day. While this tremendous crash of nature was going on, scales of various thicknesses from the various strata were shot up, detached and broken, which gave formation to our surrounding hills, the ragged cliffs of the Catskill and the bleak brow of the Andes. Some were formed at the bottom of the sea by volcanic fires; others have arisen from various causes since the great deep retired.

This order of creation he conceived to be directly in accord with the account of Moses and the sinking of the ancient continent contemporaneous with the Noachian deluge.

When the fountains of the great deep were broken up and the bottoms of those fountains became dry land, the ancient world became itself the bottom of the great deep in its turn.

During this period all surviving animal life, both human and otherwise, was conceived as confined within the limits of Noah's ark, about one year elapsing from the time the sinking took place and the ark was floated before the new earth was sufficiently dry for the occupants to disembark.

These conjectures, it will be observed, are not quite those of Werner, since the original paste constituting the globe must, according to Eaton, have been rather a mechanical admixture than a chemical solution. While the early stages of precipitation, whereby the heaviest materials were deposited in the form of concentric layers of metals, might be suggestive of a condition of solution or aqueo-igneous fusion, the subsequent deposition of the secondary rocks, which are so plainly fragmental, leaves us to conclude that he regarded the primary condition as that of a mechanical mixture or emulsion.

Eaton in his index deviated somewhat from Werner's classification also in that he placed the argillaceous slates in the transition rather than in the primitive class.[a]

American Geological Society, 1819.

The year 1819 was signalized by the organization, in the philosophical room of Yale College, of the American Geological Society, the first American society devoted mainly to geological and allied subjects. Though this continued in existence only until the end of 1828, it was productive of much good in stimulating workers throughout the country. Maclure was elected president, with Colonel Gibbs, Professor Silliman, Professor Cleaveland, Stephen Elliott, R. Gilmor, S. Brown, and Robert Hare, vice-presidents. Among the more prominent members were Akerly, Bruce, Cornelius, S. L. and J. F. Dana, Dewey, Eaton, Godon, Hitchcock, Mitchill, Rafinesque, Schoolcraft, and Steinhauer, while the names of Emmons, Harlan, Lea, Morton, Troost, and Vanuxem appear among the younger and then less prominent workers.

The society published nothing and has left little that is tangible to tell of its existence, though Eaton, in the second edition of his Index to the Geology of the Northern States, makes the following interesting comment concerning its personnel:

> The president of the American Geological Society, William M'Clure, esq., has already struck out the grand outline of North American geographical geology. The first vice-president, Col. G. Gibbs, has collected more facts and amassed more geological and mineralogical specimens than any other individual of the age. The second vice-president, Professor Silliman, his learned and indefatigable colleague in these labors, gives the true scientific dress to all the naked mineralogical subjects, which are furnished to his hand. The third vice-president, Professor Cleaveland, is successfully employed in elucidating and familiarizing those interesting sciences; and thus smoothing the rugged paths of the student Professor Mitchill has amassed a large store of materials, and annexed them to the labors of Cuvier and Jameson. But the drudgery of climbing cliffs and descending into fissures and caverns and of traversing in all directions our most rugged mountainous districts to ascertain the distinctive characters, number, and order of our strata has devolved on me. I make no pretensions to any peculiar qualifications other than that bodily health and constitutional fitness for labor and fatigue which such an employment requires.

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[a] Silliman in his review of the work (American Journal of Science, I, 1819, p. 70) called attention to the fact that the clay slate may belong either to primitive, transition, or secondary formations. He also questioned if the West Stockbridge marble should not be regarded as primitive rather than metalliferous.

During the years 1818 and 1819 Henry R. Schoolcraft made a trip throughout what is now known as the lead region of the Mississippi Valley, and in November of the last-named year published, in the form of an octavo volume of some 300 pages, a book entitled A View of the Lead Mines of Missouri; Including Some Observations on the Mineralogy, Geology, Geography, Antiquities, Soil, Climate, Population, and Productions of Missouri and Arkansas and Other Sections of the Western Country. The work contained little of geological importance, the purport of the trip being mainly to study the lead deposits of the region. He described the whole mineral country as "bottomed" on primitive limestone, though he found quartz rock and later sand rock very common in the southern section of the Arkansas country. Secondary limestone was also met with, but was far less common than in Ohio, Indiana, Connecticut, and Illinois, the ore itself being found in the decomposition products from the primitive limestone. He mentioned the occurrence of granite in Washington and Madison counties, also greenstone porphyry and iron ore, and correctly described the granite as being the only mass of its kind known to exist between the primitive ranges of the Allegheny and Rocky mountains, being surrounded on all sides and to an almost immeasurable extent with secondary limestone. He gave also a descriptive catalogue of the minerals found in the State. Among them mention was made of the flint from Girardeau County; several varieties of quartz, including the Arkansas novaculite; a red pipestone from the Falls of St. Anthony, which is evidently the catlinite of more recent writers, but which he called steatite; and other minerals, including baryte, fluorite, blende, antimony, native copper, etc. He described briefly the micaceous iron ore of Iron Mountain, the coal found near Pittsburg, Pennsylvania, and other minerals which need not be mentioned in detail.

Schoolcraft's Explorations, 1818-19.

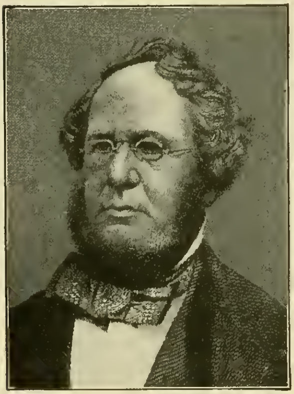


FIG. 6.—Henry Rowe Schoolcraft.

Schoolcraft was one of those all-round naturalists and investigators such as could exist only in the early days of science, when it was possible for one mind to embrace or include all knowledge, keep track of its development, and at the same time aid in its advancement. A man apparently of more than ordinary vigor, daring, and perseverence, he early became interested in the work of exploration, his field being, however, limited mainly to the Mississippi Valley and the region of the Great Lakes. His geological work was purely of the reconnaissance type, but was of the greatest value in the then existing condition of knowledge regarding the regions visited, the lead regions of the

Mississippi Valley and the copper regions of Lake Superior both profiting by his labors.

Being brought in contact with the aborigines and realizing the rapidity with which they were becoming contaminated through con-

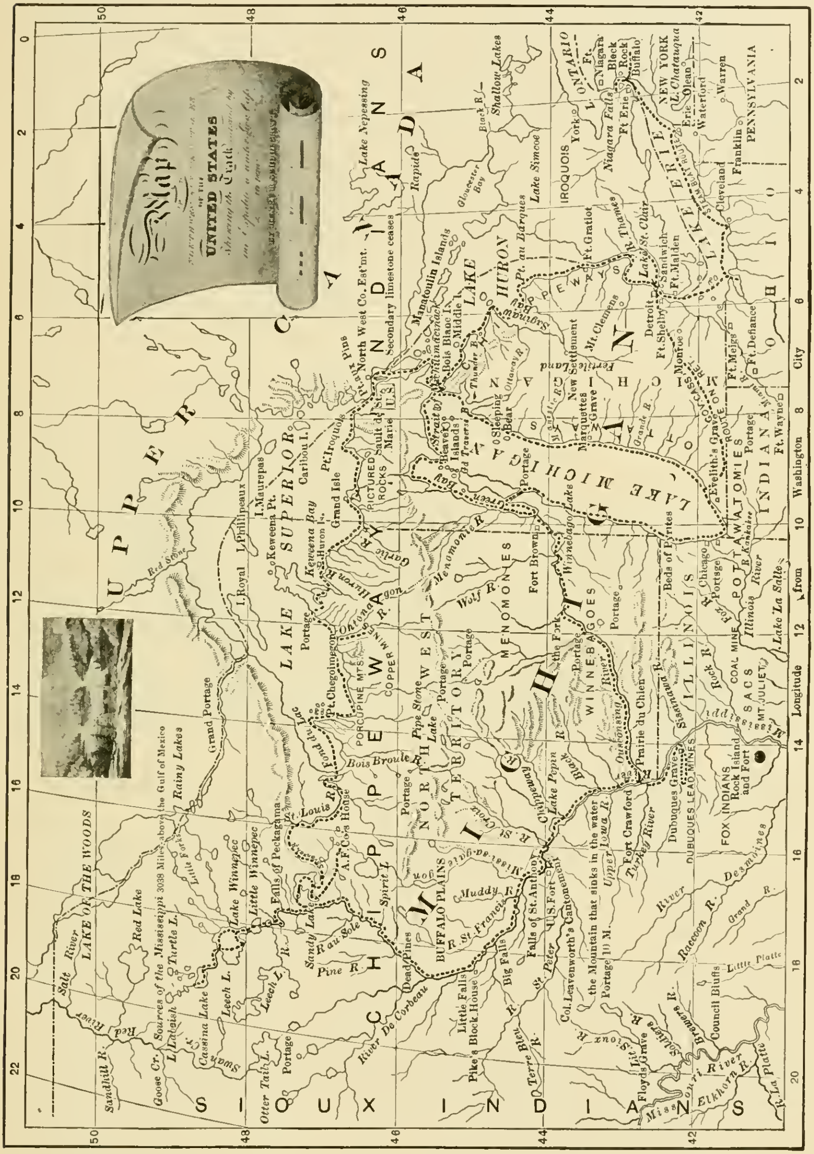
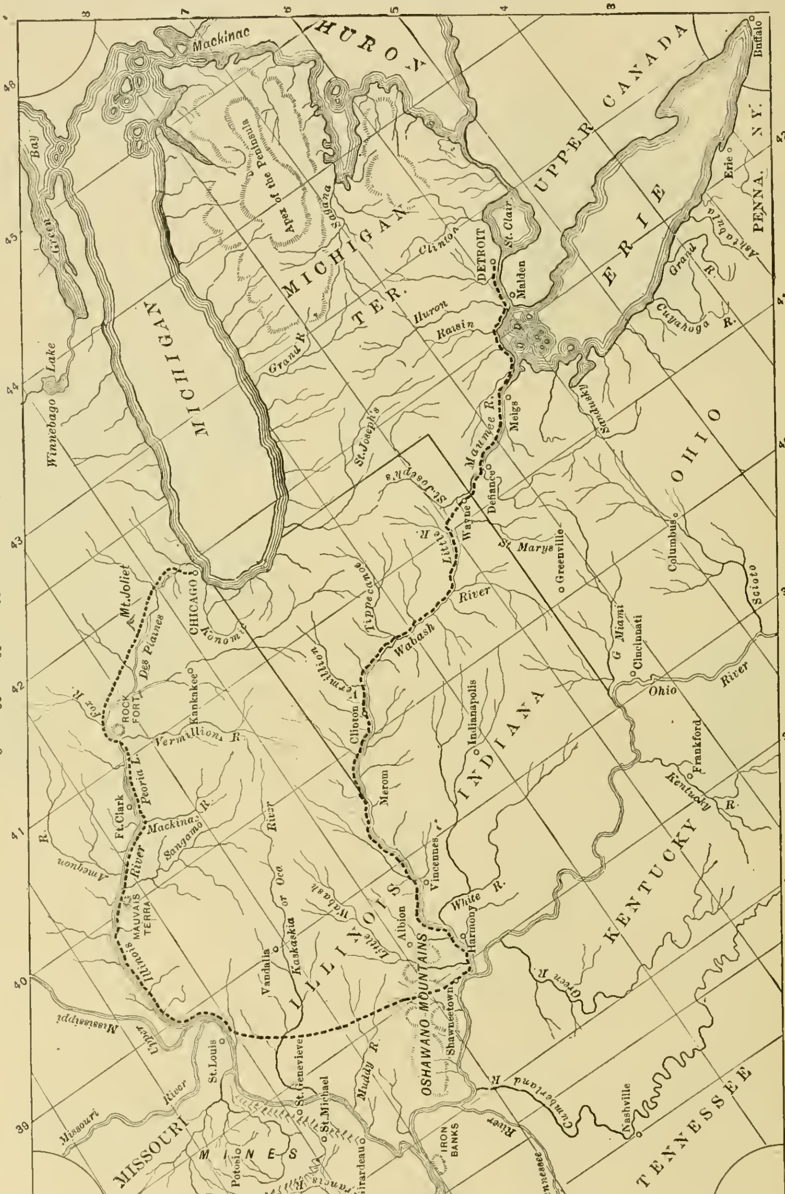


FIG. 7.—Map showing Schoolcraft's route in 1820.

tact with the whites, he was drawn into a study of the Indian tribes of North America, to which work, after 1822, he gave up a large portion of his time. The main work of his life lies, therefore, quite outside the limits of the present paper.

In 1820 Schoolcraft, acting under direction of Governor Lewis Cass, of Michigan, who was himself acting under authority of the then Secretary of War, made a trip along the Great Lakes and to the sources



A SKETCH OF THE WESTERN COUNTRY.

FIG. 8.—Map of Schoolcraft's travels in 1821 (1825).

of the Mississipppi, the results of which, with general notes on the natural history of the region, were published the year following.

In 1821 he was a member of a second expedition authorized by the General Government to explore the central portions of the Mississippi Valley, the results of which were published in 1825. In 1822 he also reported to the General Government on the extent and value of the mineral lands on Lake Superior, and again in 1832 "resumed and completed" his explorations of the sources of the Mississippi, his results appearing in book form in 1855.

The expedition of 1820 (See map, fig. 7) started at Detroit and made its way northward along the western shores of lakes St. Clair and Huron to the Straits of Michilimackinac, thence northward through St. Marys River and along the south shore of Lake Superior to Fond du Lac, up the St. Louis River, and down the Savannah to Sandy Lake and lakes Winnipeg and Cassina farther north. The return trip was made down the Mississippi to the lead region near Dubuque, Iowa, and thence northeasterly up the Wisconsin River to Green Bay, where

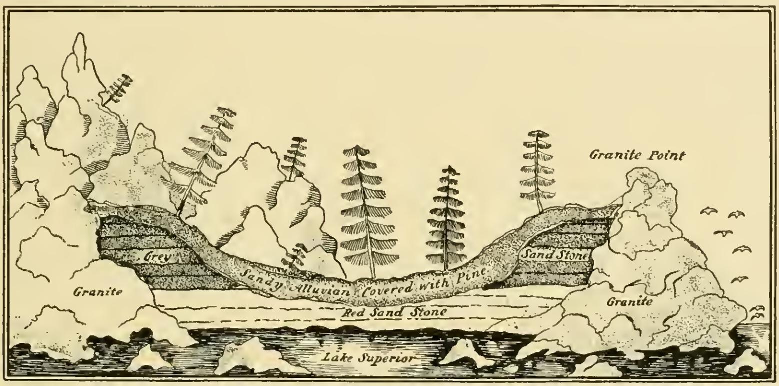


FIG. 9.—Schoolcraft's Section of Presque Isle.

the party divided, a portion going to Michilimackinac (now Mackinac), along the northern and eastern shores, and the rest keeping to the south, to Chicago, and eastward and north till the starting point was reached once more, one section of the party, with Governor Cass, leaving the lake near the southeastern end (at the mouth of the River du Schmein) and going overland to Detroit.

The narrative of the expedition of 1820 abounds with mineralogical and geological notes, which are in large part, however, of a supposed economic nature. The occurrence of gypsum at St. Martins Island was noted, the island of Michilimackinac itself being of "transition and compact" limestone. A colored section was given showing the relative position of granite and overlying sandstone between Presque Isle and Garlic River (fig. 9). The sandstone he described as overlapping the granite and fitting into its irregularities in a manner that "shows it to have assumed that position subsequently to the upheaving of the granite." The age of this sand rock he was unable to satisfactorily determine, though its position seemed to him to indicate a near alliance to the "Old red sandstone."[a]

He described the finding of the large block of native copper (now in the U. S. National Museum in Washington), upon the edge of the Ontonagon River, giving a picture and offering some remarks on the probable origin of the same. In his report to Secretary J. C. Calhoun, under this same date, made with reference to the copper mines of Lake Superior, Schoolcraft dwelt in some detail upon the occurrence of frequent masses of drift copper, but stated that no body of the metal sufficiently extensive to mine profitably had been discovered. He, however, regarded it as probable that a more intimate knowledge of the resources of the country might result in the discovery of valuable ores of copper, in the working of which "occasional masses and veins of the native metal may materially enhance the advantage of mining." This prediction, it is scarcely necessary to say, has been abundantly verified.

Writing on the prevailing theories as to the origin and distribution of metals and gems, he remarked, "There is no reason that can be drawn from philosophical investigations to prove that these substances may not be abundantly found in the climates of the north, even upon the banks of the frozen ocean," their distribution being apparently wholly independent of climatic conditions.

The Dubuque lead ore he described as occurring in detached masses in the ocherous alluvial soil resting upon a calcareous rock referable to the Transition class (in the revision of his work, published in 1832, he made this Carboniferous), and also in veins penetrating the rock. The relationship existing between the rock and the residual clay did not seem, however, to have been recognized.[b]

The presence of extensive beds of coal about 40 miles southwest of Chicago, on the Fox River, was noted. The fact that bricks, made from clay occurring near Chicago, turned white was also noted, and explained on the ground that they were lacking in iron oxides.[c]

In his "Travels" Schoolcraft advanced the idea that there had been at some former period an obstruction in the channel of the Mississippi River at or near Grand Tower, in southern Illinois, whereby there was produced a stagnation of the current at an elevation of about 130

[a] The correct position of this sandstone remained long a matter of doubt and dispute. It is now considered as of Potsdam age.

[b] Since this mode of occurrence was referred to by subsequent explorers, it may be well to state here that the ore was originally in the limestone, from which it was liberated by decomposition and left to accumulate in the residual clay, representing the insoluble constituents.

[c] This has since been shown to be an error. These clays contain as much iron as others that may burn red. It is probable that, in the process of firing, this iron combines to form an iron-lime-magnesian silicate and is not oxidized to the extent of imparting the common brick-red color.

feet above the present ordinary watermark. This was made sufficiently evident to him by the general elevation and direction of the hills, which for several hundred miles above are separated by a valley from 20 to 25 miles wide. Wherever these hills disclosed rocky and precipitous fronts a series of distinctly-marked old water lines were observed. The Grand Tower and the contiguous promontories were regarded as but the dilapidated remains of this barrier. On the breaking away of the obstructions the water gradually receded into existing channels, by which the inland sea was gradually drained.

One of the most curious features of this paper lies in his pronounced acceptation of the accuracy of the various reports relative to the finding of living animals embedded in rocks of considerable geological antiquity. He mentioned the finding at Carthage, on the Genesee, of twelve or fifteen frogs embedded in a layer of packed clay marl about 9 feet below the surface, where they had apparently been buried since the diluvial era; also the finding of one in a geode in the Niagara limestone at Lockport. As bearing upon the same subject, he gave in his addenda a series of accounts of the finding of various living animals under equally impossible conditions, which he seems to accept without question.

Long's Expedition, 1819–20.

In 1819–20 Maj. Stephen H. Long, under the direction of John C. Calhoun, Secretary of War, made an expedition from Pittsburg to the Rocky Mountains. With him were associated Thomas Say, entomologist, and Edwin James, botanist and geologist. The accounts of the expedition, compiled by Mr. James, contain numerous references to the geology of the region, which are of interest, considering the time at which they were made. The route of the expedition lay from Pittsburg down the Ohio to its mouth, up the Mississippi to St. Louis, and northwestward to Council Bluffs; thence westward along the Platte and South Platte to a point a little west of the one hundred and fifth meridian and north of the thirty-fifth parallel; across to the Arkansas, which was followed down to a point a little east of the one hundred and fourth meridian, where the party divided, one returning by the Arkansas and the other by the Canadian River.

The reports on geology were, naturally, largely tinged with Wernerism. It was noted that, in the vicinity of the Rocky Mountains, only Secondary rocks occurred, Transition forms being entirely lacking. He noted, first, the occurrence of red sandstone resting immediately on the granite, rather indistinctly stratified, the strata sometimes inclined and sometimes horizontal; second, argillaceous or gray sandstone overlying the red and conforming to it in its inclination and carrying sometimes coal and iron; third, floetz trap, including greenstone and amygdaloid; and fourth, sand and gravel resting on the sandstones and extending over the Great Desert, this latter material being recognized as a product of the disintegration of the primitive rocks of the mountains and which he thought "to have been deposited at a very remote period when the waters

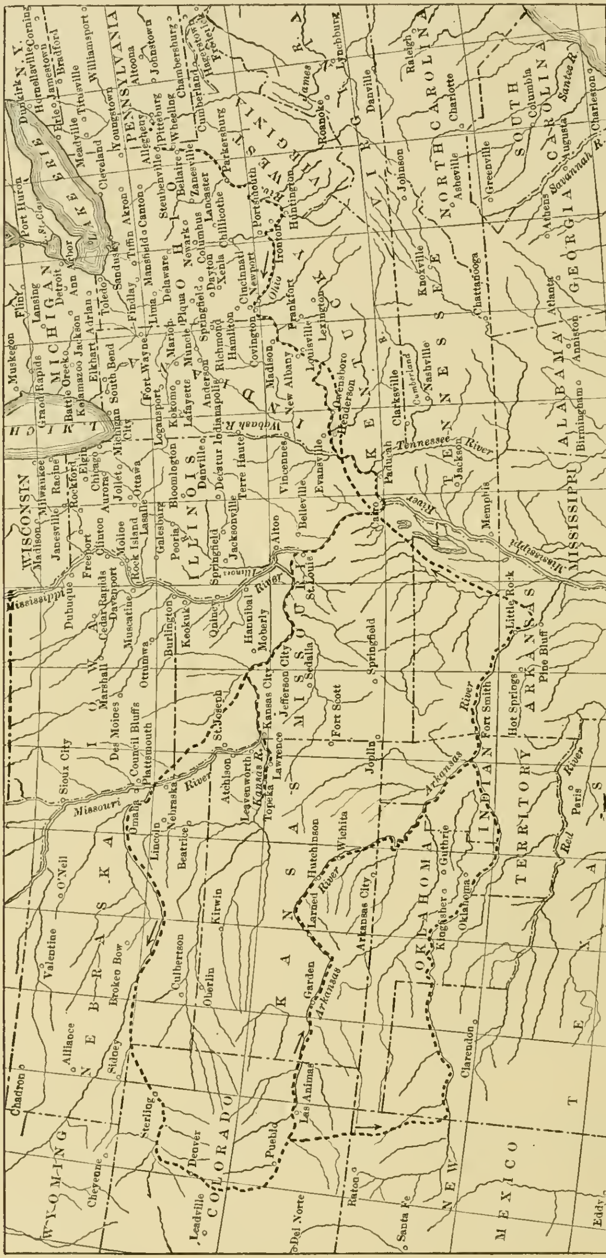


FIG. 10.—Map of Long's expeditions, 1819–20.

of the primeval ocean covered the level of the Great Plain and the lower regions of the granitic mountains." The inclined position of some of these Secondary rocks in the immediate vicinity of the mountains was noted, but some difficulty found in accounting for the same. "Subsequent to the deposition of these horizontally stratified rocks," he wrote, "their position has been somewhat changed, either by the action of some force beneath the primitive rocks, forcing them up to a greater elevation than they formerly possessed, or by the sinking down of the Secondary, produced by the operation of some cause equally unknown." This matter he again referred to, thinking it possible, though scarcely probable, that the great and abrupt change in the inclination of the strata in the parts near the granite might be due to the gradual wearing away by the agency of rivers of some portion of the sandstone, and that those rocks now found in an inclined position were detached portions of what was formerly the upper part of the strata which, having been undermined on their eastern side and supported by the granite on the western side, had fallen into their present position.

The presence of coal beds in the region of the Ozark Mountains was noted, and the associated limestones were set down as of Carboniferous age, as was also the limestone of the region of the lead mines.

James's Suggestion as to Artesian Wells.

An important suggestion was made relative to the possibility of obtaining water through bore holes sunk in the arid tract lying west of the Ozark Mountains. "It is not improbable," he wrote, "that the strata of many parts of this secondary formation toward its exterior circumference may vary from a horizontal to an inclined position, in consequence of which the water that falls in dew and rains in the hilly districts, becoming insinuated between curved stratifications, may descend toward the center of the formation under such circumstances as would insure its rising to the surface through well or bore holes sunk sufficiently to penetrate the veins."

The rocks of the Allegheny Mountains were classified as granular limestone, metalliferous limestones, transition, argillite, and sandstone. The report was accompanied by a volume of plates, which included geological sections on the thirty-fifth and forty-first parallels (fig. 11). These were intended to form continuations of Maclure's third and fifth sections, already noted (p. 228).

Geological Notes by Silliman, Olmsted, and Atwater.

The second volume of Silliman's American Journal of Science, issued this year, had a long article by the editor—Sketches of a Tour in the Counties of New Haven and Litchfield, Conn., with notices of the Geology, Mineralogy, and Scenery—in which are described the various rocks passed over, among others the "primitive white marble" near New Milford. He described this as "a perfectly distinct bed in gneiss, which is found on both sides of it, and, of course, both above and below it," a sensible admixture of the two rocks being perceptible for some feet on both sides of the junction.

Just what Silliman's preconceived opinions may have been is not apparent, but he remarked in a satisfied way that the associations were exactly what he had anticipated.

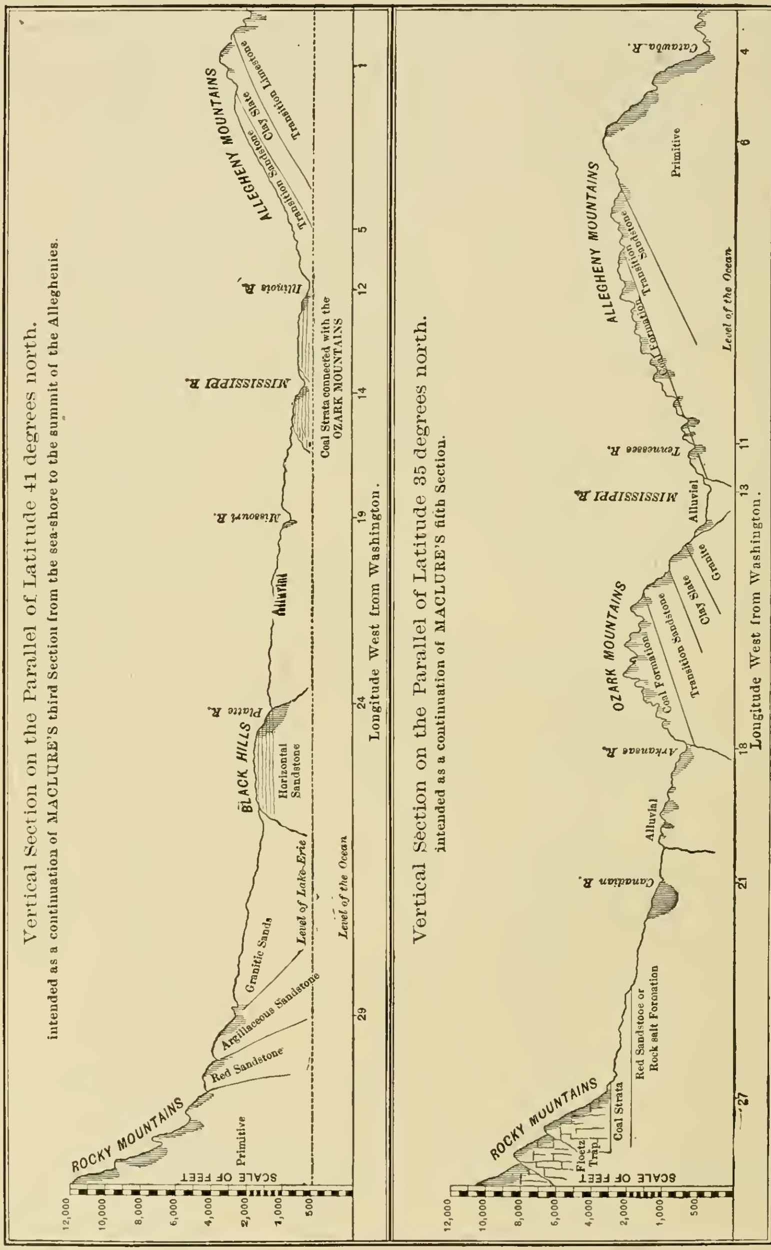


FIG. 11.—Geological Sections from the Allegheny to the Rocky Mountains. (After Edwin James.)

The geological relations of the marble appear to have been perfectly distinct, * * * and give us new reason to admire that wonderful order and harmony, little expected by people in general, which are found equally in the mineral kingdom as in the animal and vegetable, and which afforded on analogical grounds the best reason to predict that the geological association of this marble would be found to be what it actually is.

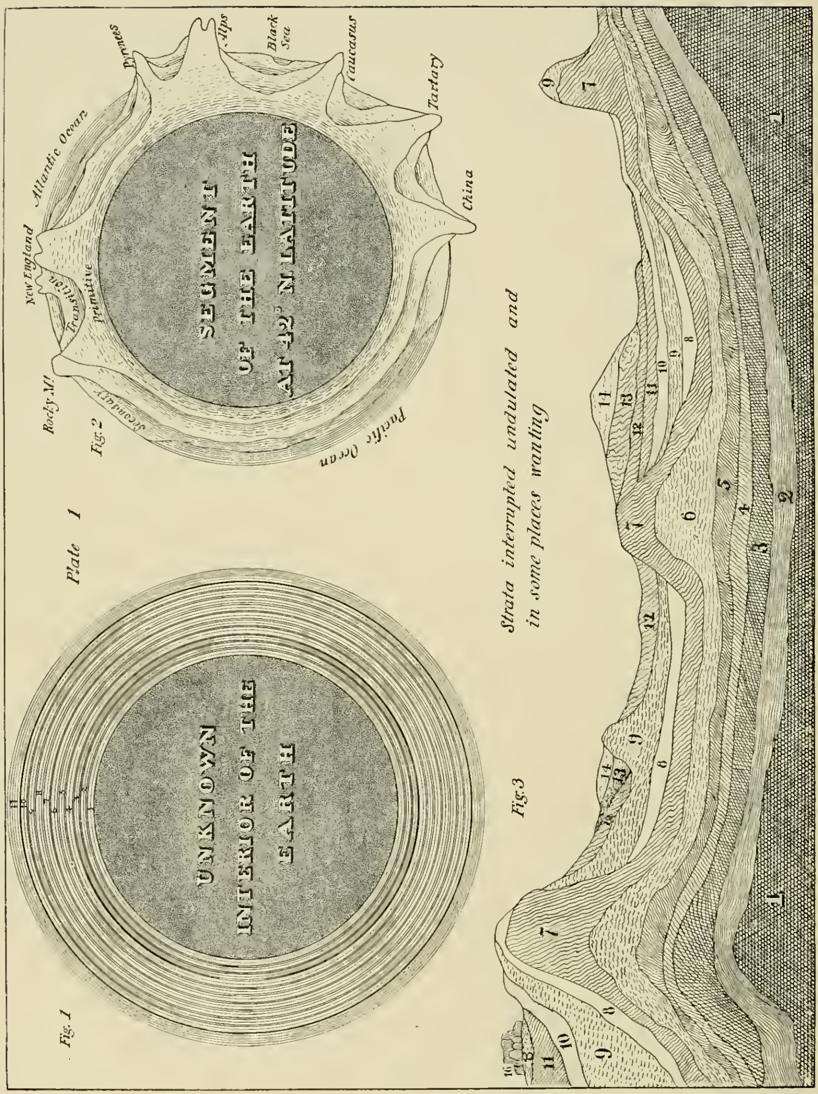
In the district are nearly all the important primitive rocks of Verneuil, while New Hampshire includes a considerable portion of his secondary formations.

In the same Journal, Denison Olmsted, then at Chapelhill, in North Carolina, announced the discovery of a red sandstone formation in North Carolina, which he had traced through the counties of Orange and Chatham, with a breadth, in one instance at least, of about 7 miles.

Caleb Atwater, in the same volume, noted the occurrence of ancient human bones, together with those of a mastodon or mammoth in Ohio, which indicated to his mind that the whole country had at one time been covered with water, which had made it "one vast cemetery of the beings of former ages."

Akerly on the Geology of the Hudson River, 1819.

In August, 1819, Dr. Samuel Akerly, who is first mentioned on page 223, read before the New York Lyceum an essay on the geology of the Hudson River and vicinity. This was published the year following in the form of a small duodecimo volume of 69 pages, and was accompanied by a colored section of the country from the neighborhood of Sandy Hook, New Jersey, northward through the Highlands in New York toward the Catskills. This section is mainly interesting as being the second attempt of its kind, being preceded by Eaton's transverse section from the Catskills to the Atlantic by only two years. The work consisted mainly of descriptive details relating to the lithological character of the various formations, and contained little else of value. Akerly was a disciple of Mitchill, whom he followed implicitly. He, however, questioned the Old Red Sandstone age of the Connecticut River sandstones, on account of bones of land animals having been found beneath them at Nyack. Since, however, credence is given to the reported finding of pine knots, earthen vessels, iron instruments, corn cobs, etc., under these same sandstones, and an iron instrument resembling a pipe in the anthracite coal of Rhode Island, little weight can be given even to his doubts.



EATON'S GEOLOGICAL SEGMENTS, 1820.

CHAPTER II.

THE EATONIAN ERA, 1820–1829.

According to Amos Eaton, 1820 marked the close of the first era of American geology. Accepting this, it may well be called the Maclurean era. The second, including the decade 1820–1829, may with equal propriety be called the Eatonian era, since Eaton was the most prominent worker as well as most profuse writer of the decade. In so doing, however, we must not overlook the fact that Eaton was favored with unusual opportunities, owing to the munificence of the Hon. Stephen Van Rensselaer and that he, himself, would perhaps have called it the Rensselaerian era.

The era opened with promise, and though the results as apparent on paper were not great, yet much was actually accomplished. It was, so to speak, a transition period, one in which the possibilities of State and Governmental surveys were seriously considered, and one, too, in which, so far as America was concerned, there was made the first systematic attempt at correlation by means of fossils. We meet, too, during this interval the first really satisfactory suggestion as to the source of the glacial drift, the first recognition of overturned folds and the possibility of the repetition of strata through faulting and displacement. The cosmogonists had largely disappeared and in their place were men who had learned to first observe and then deduce according to their understanding of the observed phenomena.

Second Edition of Eaton's Index, 1820.

In 1820 Eaton published a second edition of his Index in the form of a small octavo volume of 286 pages. In this many of the earlier opinions were restated with little, if any, modification. His views relative to the origin of the continents were illustrated by the plate here reproduced, but the source of the energy which resulted in the elevation of the continents was still unexplained. He asserted:

> That the rents made by the grand explosion, which first upturned and disfigured the rocky crust of the earth, were in a north and south direction. That those crossing the forty-second degree of north latitude were principally made at the Pyrenees and Alps in Europe, Caucasus, Tartary, and China in Asia, Rocky Mountain and New England in America.
>
> Whether this theory accords with the real origin of the present state of things or not is immaterial. It is introduced solely for the purpose of aiding the memory in studying the strata which we know do exist.

His views regarding the formation of caves in limestone were primitive and highly interesting:

When the waters of the ocean retired, the calcareous cement which now holds the shells together was in a state of soft paste. * * * After the waters retired the parts exposed to the sun's rays began to harden, contract, and crack into blocks. In some parts of the Helderberg these blocks are of great extent, but I have seen acres of it where the stratum is very thin, checkered up into blocks from 2 to 10 feet square. Where the stratum is very thick and the fissures very long, large caverns were frequently formed, for the upper surface of the stratum was soon dried and indurated, while the whole remained soft a long time a few feet below the surface. If a stream of water happened to flow in the vicinity of the fissure, it would probably make its way into it and soon wash away the loose shells beneath the surface, which were merely enveloped in soft calcareous paste.

And further:

I have examined four of the largest caverns in the Helderberg, and they all still exhibit conclusive evidence of their having been once in the state of mere fissures, and streams of water still traverse them all.

The majority of readers of to-day need scarcely be told that these limestone caves are formed wholly by a process of solution, by surface waters acting upon the strata only after they had reached, essentially, their present position and condition of induration. The streams of water which are found traversing the caves are incidental and consequent rather than causative.

His views on the formation of stalactitic iron ore, as exemplified in the Salisbury mine, are equally interesting. The ore, he believed to have been at one time specular iron imbedded in the talco-micaceous rock, and deposited in its present form from a state of fusion as recent as the time when the "Alluvion" was formed.

These stalactites are always suspended from masses intermixed with the soil in such a manner that it is evident the iron was in a state of fusion when in contact with it. The foot, which still adheres to all stalactitic specimens, proves that the heat was continued after the ore was confined in its present state. If it was ever fused down from any rock, it must have been the same out of which the alluvion embracing it was formed. The cause producing such a high heat I shall not attempt to assign; but that the ore exhibits sufficient evidence of its having been recently fused, I believe no one can question who has ever inspected it in place.

The reader of to-day need here also scarcely be told that all the peculiarities thus described were due not to heat, but to deposition from solution.

His views regarding many phenomena were, naturally, largely a reflection of those held by European authorities. In fact, one of the most striking features which impresses itself upon the reader of these early works is the attempt manifested by all to correlate the various formations, not of America alone, but American with European, on purely lithological grounds. If a specimen of sandstone, schist, or whatever it might be, resembled another from a different source, no matter how distant, this was considered evidence of its belonging to the same formation. This method of correlation did not wholly disappear among American workers for many years, although Marcou was probably its latest ardent apostle. Eaton himself made an attempt to break away from it in his later work, as will be noted.

In the work under discussion the crystalline limestone or granular limestone and quartz, calcareous and granular quartz, and metalliferous limestone of the first edition were regarded as all belonging to one and the same stratum, but the position of this limestone, as shown near the east line of Danbury, Connecticut, confused him.

Here the layers dip to the west; but in West Stockbridge and Alford they genally dip to the east, though there seems to be no conformity in their direction. Had some force, applied at the eastern edge, raised these mountain masses from the horizontal toward the vertical position, leaving some inclined to the east and forcing others beyond a vertical position, they would have presented their present inclination.

This is the first suggestion of anything resembling an overturned fold which had thus far been made. He was correct in his observations, but the science had not sufficiently advanced to enable him to realize the possibilities. It will be noted, too, that he was working in a region, the correct interpretation of which has been a source of dispute for nearly three-quarters of a century. The glacial drift was, as in the first edition of his work, still classed as alluvial, and the materials composing Long Island and the coastal plain were regarded as of a common origin.

Eaton made use of Le Duc and Jameson's awkward name of *Geest* to include the "most universal of all strata," which was found occupying "every inch of dry land which is neither naked rock nor covered with alluvion," and the character of which "is generally indicated by the rock upon which it lies and by those which have recently disappeared." Although thus defined, in his attempt to outline its distribution he failed to discriminate between the true residual material and that which is drift.

What he had to say on the subject of organic relics or fossils was merely an adaptation from Martin's *Systema reliquiorum*. He classified these relics under two heads, *petrifactions* and *conservatives*. The petrifactions or *substitutions*, as he sometimes called them, were "those relics which are entirely made up of mineral substances, which have gradually run into the places occupied by organized bodies, as those bodies decayed, and assumed their forms." The conservatives or preservations, on the other hand, were "those relics or parts thereof which still consist of the very same substances which originally composed the living, organized being."

These relics were named by annexing the termination *lithos*, a stone, to the scientific name of the living organism; as, for instance, a fossil fish would be ichthyolithos, though the terminology in English he often modified from *lithos* to *lite*. Adopting this nomenclature, he grouped all organic relics under nine heads, as follows: Genus I, Mammodolite; Genus II, Ornitholite; Genus III, Amphibiolite; Genus IV, Ichthyolite; Genus V, Entomolite; Genus VI, Helmintholite; Genus VII, Concholite; Genus VIII, Erismatolite; Genus IX, Phytolite.

Eaton's Survey of Rensselaer County.

In 1821 Eaton was employed by S. Van Rensselaer to make a geological and agricultural survey of Rensselaer County, New York. His report, printed in 1822, formed an octavo pamphlet of 70 pages, and was accompanied by a geological section, extending from the Onondaga Salt Springs across the county to Williams College in Massachusetts. The first thirty pages of the report were given up to discussions of the character and distribution of the various kinds of rocks and soils, and the remainder to methods of culture and an agricultural calendar.

The rocks of the county, as well as those of Washington County on the north and of Columbia County on the south, were regarded as chiefly belonging to the transition formations. Secondary limerock resting on the graywacke was found in Schaghticoke about four miles east of the Hudson and in the northern part of Greenbush. As to whether the argillite along the eastern margin of the county was transition or primary, he was in doubt. As with his contemporaries, he based his opinions largely upon lithological data, quite failing to realize that rocks of widely varying age may more or less resemble each other, according to local conditions and the amount of metamorphism they may have undergone. Passing westward from Williams College, the various rocks met with, as shown in his section, and described are (1) granular and primitive limestone, (2) metalliferous or transition limestone, (3) argillite, (4) metalliferous limestone again, (5) a second band of argillite, (6) graywacke with sporadic patches of (7) compact secondary limestone, (8) secondary or calcareous sandstone, and (9) argillaceous graywacke, semi-indurated argillite, and clay slate. The first three were represented with steep westerly dips passing under the graywacke, which constitutes the principal formation.

J. B. Gibson on Trap Rock, 1820.

On November 17, 1820, the Hon. J. B. Gibson read a paper before the American Philosophical Society, which was published in the Transactions of that year, on the trap rocks of the Conewago Hills near Middletown, Dauphin County, and Stony Ridge near Carlisle, Dauphin County, Pennsylvania. He described the mode of weathering into bowlders, and rightly argued that such was due wholly to atmospheric agencies and did not indicate an original concretionary structure. He seemed to regard the columnar structure in this class of rocks as due also to decomposition, mentioning as an example the columns of the Giant's Causeway, "which exhibit regular prismatic form only when it has long been exposed to the action of the atmosphere."

He did not regard the trap of the Conewago Hills as igneous, but that of Stony Hill presented to him an appearance more decisively volcanic. This did not, however, necessarily mean that there may have once existed a crater here.

These observations of Gibson relative to the mode of decomposition of the trappean rock are of interest when taken in connection with observations of other individuals of about this period in North Carolina.

It appears that the attention of the Rev. James Hall and Zachariah Lewis had been called to what are now known to be small trappean dikes on the Yadkin River, near Salisbury, which had undergone decomposition into small bowlder-like masses. The fact that these dikes had at one time occupied rifts in older rocks which had largely disappeared through decomposition, leaving them standing in wall-like masses, entirely escaped the observation of the two gentlemen named, and they were consequently described as probably of human workmanship.

In response to a request of Dr. Samuel L. Mitchill, Mr. John Beckwith made an examination of the occurrences and reported the result in a letter printed in the American Journal of Science for 1822. Beckwith described in considerable detail the occurrence of the dikes and the stages of transition from the solid bowlder-like masses to the supposed interstitial cement. While apparently not realizing completely the fact that their then appearance might be due to decomposition, his description is such as to leave no doubt in the mind of the present reader. As to the exact character of the material itself, he was somewhat at a loss, but, on the whole, inclined to believe it to be basaltic, though perhaps of aqueous rather than ignecus origin.

The work of Thomas Nuttall merits attention here only on account of the time of its accomplishment. Nuttall himself was not a geologist, nor can he be considered an American. His principal work was of a botanical and ornithological nature, the paper, Observations on the Geological Structure of the Valley of the Mississippi, being his sole contribution to the literature of geology. This was read before the Philadelphia Academy in December, 1820, and in its printed form occupies 38 pages of the journal of the society.

Nuttall's Observations, 1820.

Nuttall's travels took him along the southern shore of Lake Erie to Detroit; thence by canoe along the coast of Lake Huron to Michilimackinac; thence southwestward to Green Bay, Wisconsin, and by way of the Fox and Wisconsin (Ouisconsin) rivers to the Mississippi, near Prairie du Chien, and southward to St. Louis. This and other trips up the Missouri and Arkansas rivers gave him ample opportunity for such superficial observations as he was competent to make. These observations consisted largely of conjectures as to the geographic limits of the secondary formations, which he found here to consist mainly of limestone strongly resembling the mountain limestone of Derbyshire in England, and he announced himself as "fully satisfied that almost every fossil shell figured and described in the Petrifica Derbiensia of Martin" was to be met with throughout the great calcareous platform of the Mississippi Valley. The limits and character of the "Ancient Marine Alluvium," its fossil and mineral contents were discussed; the essay concluding with some observations on the Transition Mountains of Arkansas, with brief notes on the hone slate of Washita.

In 1820 there appeared also H. H. Hayden's Geological Essays. These are of especial interest as dealing particularly with the Tertiary and more recent alluvial deposits of the Atlantic and Gulf coasts, forming what is now known as the coastal plain. The work is verbose in the extreme and more argumentative than logical. Indeed, were it not for its historical interest and for the light which is thrown upon the crudities of early observation and deduction, it would be scarcely worth considering at all.

Hayden's Essays, 1820.

After referring to the geographical limits of this coastal plain, as defined and mapped by Maclure, and combating the opinions of previous observers [including Latrobe, Stoddard, and others] to the effect that it was formed by flood tides and the winds acting on materials cast up by the sea or through the transporting powers of the great rivers, Hayden proceeded to elaborate his own theories in a way as ingenious as it now seems improbable. "Viewing the subject in all its bearings, there is no circumstance that affords so strong evidence of the cause of the formation (i. e., the coastal plain) as that of its having been deposited by a general current, which at some unknown period flowed impetuously across the whole continent of America, and that from northeast to southwest." The course of this current he assumed depended on that of the general current of the Atlantic Ocean, the waters of which rose to such a height that "it overran its ancient limits and spread desolation on its adjacent shores."

In seeking a cause for this general current the author referred, first, to the seventh chapter of the book of Genesis, "For yet seven days, and I will cause it *to rain* upon the earth forty days and forty nights, and *every living substance that I have made will I destroy from off the face of the earth.*" He then proceeded to show the inadequacy of this cause alone; the water being thus equally distributed over the ocean and the land, there "could be no tendency to cause a current in the former." Some other cause must therefore be sought, and fortunately his imagination proved equal to the task.

Accepting as probable the suggestion of "a writer of no common celebrity," presumably Kirwan, to the effect that the cause of the general deluge was the melting of the ice at the two poles of the earth, and that this was occasioned by the sun deviating from the ecliptic, he proceeded to explain in his own way how this might be brought about, though acknowledging that no positive testimony could possibly be adduced to substantiate the fact.

Having admitted the possibility of the earth's changing its position so that the sun would pass "immediately over the two poles upon an unknown meridian," he showed that there would then result a rapid dissolution of the existing ice caps, such as would yield an ample supply of material, it being only necessary to give it direction. Considering as essential to the problem only the northern hemisphere, he remarked that from this polar cap there are but two outlets—the one into the Pacific Ocean through the narrow Bering Strait and the other through the wider channel between Greenland and Lapland into the Atlantic. Hence, when the melting ensued, by far the larger volume of water passed into the latter ocean.

No sooner was this operation established, and this accession of strength and power thrown into the Atlantic Ocean in particular, than its tide began to rise above its common limits accompanied by a consequent current, both constantly increasing, the one in height and the other in rapidity, proportioned to the increase of power at the focus. * * * At the commencement of this frightful drama the current, it is highly probable, was divided by the craggy heights of Spitzbergen and a part thrown into the White Sea, while the other was thrown back upon the eastern and southern coast of Greenland, and from thence in a southwestern direction until it struck the southeastern coast of Labrador, along which it swept through the straits of Belle Isle, across Newfoundland, Nova Scotia, and along the Atlantic coast into the Gulf of Mexico. * * * In a short space of time, the southern and eastern coast of Labrador, over which this current was urged with increasing force, was desolated. The soil * * * was hurled adrift and * * * carried across the country into the Gulf of St. Lawrence, and across a part of New England into the sea, or general current of the ocean. Continuing to rise, the waters swept across Davis Strait and rolled their tumultuous surges into Hudson Bay, embracing the whole coast of Labrador, while the unequal current of the St. Lawrence was *forced back and upward to its parent source.* * * *

At length the floods of the pole forming a junction with Baffins Bay and the Arctic Sea, defying all bounds, overran their ancient limits and hurled their united forces, in dread confusion, across the bleak regions of the north to consummate the awful scene. Thus lakes and seas uniting formed one common ocean which was propelled with inconceivable rapidity across the continent between the great chain of mountains into the Gulf of Mexico and probably over the unpeopled wilds of South America into the Southern Ocean. Fulfilled in this way were the awful denunciations of an offended God, by the sure extermination of every beast of the field and every creeping thing that creepeth upon the face of the earth.

The argument used to substantiate or in favor of the probability of the above causes can not be dwelt upon here. But to these causes he believed to be due not merely the alluvial deposits of the coastal plain, but as well the barrenness of soil of the rocks in Labrador and the northeastern portion of the continent, and also the general phenomena of the glacial drift, the bowlders of the latter being conceived as transported by floating ice.

While all this was taking place on the American continent, the material supplied by the melting of the south Polar ice cap was finding its way northward over Asia, carrying with it to northern Siberia the mammoth, rhinoceros, and other gigantic animal remains now there found. In this last, it will be observed, he followed Pallas.

The opinion held by many to the effect that the deltas of rivers were composed exclusively of alluvion brought down in the course of time and deposited at their mouths, he regarded as "a flagrant dereliction from truth and every principle of sound reasoning and established fact." Such he regarded as formed in part of natural alluvion of the rivers, in part of wind-blown sand and dust, and in part of waste from the fields due to cultivation and the cutting away of forests. Thus early he recognized the importance of man as a geological agent, and also that of the wind. He nowhere in the whole 150 pages of the discussion, however, recognized the now well-known fact that deltas are formed only at the mouths of rivers emptying into tideless seas.

Strangely enough, although one of the earliest to recognize the extent and importance of the alluvial formations, Hayden seems to have had very hazy notions regarding the origin of their materials. The belief held by many to the effect that every species of rock is liable to a slow but progressive form of disintegration and decomposition was to him rank heresy, as "tantamount to a libel against the letter and spirit of Holy Writ." Not but that some rocks may indeed decompose, such as the "micaceous schistus," but "granite and other rocks of like nature, where the quartz feldspar and mica are perfectly combined, are practically indestructible;" and the arguments he used to prove this are precisely those used to-day to prove the rapidity of the destructive process—that is, the evidence furnished by old stone monuments and buildings. Blinded by his religious prejudices and preconceived notions, he refused to accept proof of such decay, even when confronted by it in unmistakable forms, referring to such as but the "débris of the incompact or imperfectly formed mass that served as the covering, as it were, of the rocks, and which, being destitute of a cement, had fallen away to sand."

Even that "the soil which covers the face of the earth was produced by the disintegration of rocks" was to him an opinion unfounded both in natural as well as in moral philosophy, and betrayed a want of attention to the plans of the Omnipotent. "Who can or will contend that the mountains of our earth are becoming more and more depressed by the disintegration of the rocks of which they are composed? * * * Fortunately, however, it is not so. The Great Author of Nature intended it otherwise, and they are, and ever have been, the same in height, in all human probability, that they were from the commencement of time."

Hayden was the first to suggest the name *Ternary* for formations of alluvial origin and more recent than the secondary. The secondary formations he regarded as "the results of a natural operation;" that is, as natural deposits from water, probably in a state of perfect tranquility. The alluvial, on the other hand, were the results of "accidental operations."

These essays were very favorably reviewed by Silliman in the third volume (1821) of his journal, even the idea of the fusion of the polar ice cap being allowed to pass with no more serious criticism than to suggest that the flood of waters might have been produced through the expulsion of the same from cavities in the earth. J. E. De Kay, writing in 1828, ventured, however, to take exception to some of the expressed views regarding drift bowlders. He wisely suggested that since the speculative part of geology is but a series of hypotheses we should in every case admit that which explains the phenomena in the simplest possible manner. To his mind the simplest manner of explaining the presence of bowlders of primitive rocks scattered over a secondary or alluvial region was to suppose that such had been, as igneous materials, extruded through all superincumbent strata, forming peaks which have since been destroyed by some convulsion of nature or by the resistless tooth of time, the bowlders thus being but fragments which had escaped destruction, though their place of extrusion had become completely obscured.


Fig. 12.—Horace H. Hayden.

Sketch of Hayden.

Hayden's career was varied and interesting. Early thrown on his own resources, with an ardent desire for knowledge and craving for travel, he went to sea at the age of fourteen, making two voyages to the West Indies, after which he returned to his school and his books. When sixteen years of age he was bound out to an apprenticeship with an architect, with whom he served until he reached his majority, when he once more sailed for the West Indies and established himself at Point à Pitre in Guadeloupe Island, one of the Lesser Antilles. Ill health, however, finally drove him back to America, where he found employment in his profession in Connecticut and New York, with occasional intervals of teaching, in which, it was stated, he was very successful.

Through accident his attention was turned to dentistry, and with no preliminary training and only such knowledge as could be gained by reading, he established himself in the practice of that profession in Baltimore, somewhere about 1824, being then, it will be observed, between fifty and sixty years of age. In this work he is represented as being highly successful, rising rapidly in public confidence and holding the highest professional rank in the city. When the American Society of Dental Surgeons was established, he became its first president. Aside from his profession he devoted himself to studies in physiology and pathology, as well as geology.

Wilson's Exceptions to Hypotheses of Mitchill. 1821.

To Volney and Mitchill's hypotheses (mentioned on p. 232) to the effect that the deep gorge of the Potomac at Harpers Ferry, of the Hudson at West Point, the Delaware near Easton, the Schuylkill northwest of Hamburg, and the Susquehanna below Harrisburg, were torn open by the pressure of the waters of Lake Ontario, Mr. J. W. Wilson, in the American Journal of Science for 1821, took exception. He gave altitudes showing that the waters of the supposed lake could never have risen within 500 feet of the summit of the highlands at West Point without discharging over the summits of the mountains at Harrisburg; or through Lake Champlain into the Sorel and St. Lawrence before rising within 1,400 feet of Butler Hill, near West Point. These were good arguments, but the explanations offered by Mr. Wilson were in themselves by no means satisfactory. "Is not" he wrote "the best theory of the earth, that the Creator, in the beginning, at least at the general deluge, formed it with all its present grand characteristic features?" To this the editor (Silliman) responded in a footnote that "The Creator undoubtedly brought all matter into being and established the laws which govern it; the operation of those laws then is always a fair subject of discussion, and although it is the *shortest* it is not the most *instructive* course to *cut the knot* where it may be *untied*."

Early accounts of the geology and mineralogy of North America were eagerly seized upon by foreign scientists, as well as those interested from a spirit of gain only. Thus, in 1822 there was published in Hamburg, in the form of a small octavo pamphlet of 124 pages, a series of extracts from the American Journal of Science and Journal of the Academy of Natural Sciences, entitled Beitrage Zur Mineralogie u. Geologie des Nordlichen America's nach Amerikanischen Zeitschriften bearbeitet von Heinrich von Struve. The articles abstracted were Schoolcraft's account of the native copper on the north shores of Lake Superior;[a] A. G. Jessup's geological and mineralogical observations on a portion of the northern border of New York;[b] Vanuxem's description and analyses of the Wollastonite (Taffelspath's) of Willsborough, New York;[b] John Dixon's mineralogical and geological observations on a part of North and South Carolina; Gerard Troost's description of a mineral resembling amber found in the sands

[a] American Journal of Science, III, 1821, No. 2.

[b] Journal of the Academy of Natural Sciences, Philadelphia, December, 1821.

of Cape Sable;[a] and miscellaneous notes on the geology and mineralogy of North America from the same publishers.[b] There was also given a description of a collection of North American minerals. A little over four pages were devoted to a description of the marbles of Pennsylvania; Connecticut; Vermont; Stockbridge, Massachusetts; and Thomaston, Maine, the descriptions being naturally limited to specimens and not to their occurrence in the field.

In 1822 Dr. Thomas Cooper, president of South Carolina College, published in the American Journal of Science an article of nearly forty pages, giving his views on volcanoes and volcanic substances.

Thomas Cooper's Ideas Concerning Volcanoes, 1822.

He defined a volcano as a natural vent in the crust of the earth, made by subterranean fires to afford exit for gases, vapors, and solid substances that have been exposed to the action of intense heat in the bowels of the earth. The seat of the volcano he believed to be below or within the oldest granite. In action, the volcano is described as giving off smoke and flame derived from contact with coal strata, the eruption being usually accompanied by electric light, the source of which he acknowledged as problematical. Compared with all this error, his recognition as lavas of the porphyries in the vicinity of Boston and the Triassic traps of the eastern United States stands out in remarkable contrast.

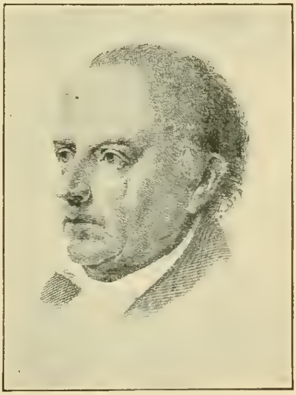


Fig. 13.—Thomas Cooper.

Cooper, or "Old Coot," as he was called during the period of his activity at the South, seems to have been a queer character—"a learned, ingenious, scientific, and talented madcap," as President Adams is said to have called him.

Sketch of Cooper.

He was not a geologist, excepting in books, but rather an educator and theorist. He was born in London in 1759 and educated at Oxford, where he paid chief attention to the classics, though his inclination was for the sciences. He came to America in 1795 and settled down for a time to the practice of law at Northampton, Pennsylvania.

A restless, aggressive spirit soon took him into the political field, where the violence of his newspaper attacks caused him at one time to be imprisoned for six months and fined. After his release he was appointed first land commissioner and then judge, being removed from the latter office for arbitrary conduct. He then turned his attention to chemistry and became in turn professor of chemistry in Dickinson College in Carlisle, professor of chemistry and mineralogy in the University of Pennsylvania in Philadelphia, and professor of

[a] American Journal of Science, 1821.

[b] Volume IV, 1822, No. 2.

chemistry, mineralogy, natural philosophy, and law (!) in the University of Virginia. At the last named place he served from 1817 to 1820, being finally forced to resign on account of the opposition to his liberal teachings on the part of the Presbyterians.

From Charlottesville he went to Columbia, South Carolina, where he served as professor of chemistry (1820–21) and then as president (1821–1834), being here again compelled to resign for his violent liberalism in matters relating to science and religion. Queerly enough, a committee appointed by the State legislature in 1831 to investigate his conduct with a view to his removal failed to make out a case, and the charges were dismissed. His final undoing would seem to have been parallel with that of the sick man whose case his physician was unable to diagnose specifically and the record of whose death was put down to "general cussedness."

Cooper, as above noted, was not a geologist, as the term is now used, but comes in for recognition here on account of the prominent part he played in early educational movements relating to the introduction of the science in the universities. It was through his influence that the chair of geology at the South Carolina College was established, to which Vanuxem was called in 1821, and Le Conte in 1857. At the time Cooper assumed the reins in Columbia geology was taught at no other institution in America except Yale, and the only available text books were the reprints of Bakewell's geologies with Silliman's notes. To the latter, on account of the acceptation of Mosaic doctrines, Cooper took violent exception, and attacked them, first in lectures to his classes and subsequently in his pamphlet on The Connection between Geology and the Pentateuch (published in 1833).

A man of powerful intellect, but a reckless busybody. Bold and aggressive, he "walked roughshod over men's opinions and suffered the inevitable consequences." His personal appearance must have been as peculiar as his conduct. "He was less than 5 feet high and his head was the biggest part of the whole man. He was a perfect taper from the side of his head down to his feet. He looked like a wedge with a head on it," is the way it is expressed by one of his old pupils.

Supposed human footprints in limestone, 1822.

The credulity of even the scientific men of this date (1822) can not be better illustrated than by referring to an account by Schoolcraft of the finding of supposed human footprints in limestone belonging to the "Secondary" formation (Lower Carboniferous), on the west bank of the Mississippi River at St. Louis. These so-called footprints (see fig. 14) were described as those of a man, standing erect, with his heels drawn in and his toes turned outward. The distance between the heels by accurate measurment was 6¼ inches, and between the toes 13½ inches. Attention was called to the fact that the impressions were not those of feet accustomed to a close shoe, the toes being too much spread and the foot flattened. The length of the foot was 10½ inches, width across the spread toes 4 inches, and at the swell of the heels 2½ inches. Public attention was first called to these prints by the Rev. Frederick Rapp, the head of the religious sect "Harmonites," who had them removed to his village of Harmony, and who, it is said, taught that they were the impressions of the feet of the Saviour.

According to Schoolcraft, every appearance warranted the conclusion that the impressions were made at a time when the rock was soft

FIG. 14.—Supposed human footprints in limestone. (After D. D. Owen.)

enough to receive them by pressure, and the marks of the feet were natural and genuine. In this opinion, he stated, Governor Cass coincided. He acknowledged, however, there were difficulties in the way of accepting this belief, and one of these was the want of tracks leading to and from them. He could only account for this on the supposition that the toe prints might have pointed inland, "in which case we should be at liberty to conjecture that the person making them had landed from the Mississippi and proceeded no farther into the interior."

Col. Thomas H. Benton, of Missouri, to whom Schoolcraft wrote concerning the footprints, differed with him and regarded them as artificial, but his reasons therefor were not sufficient to convince Schoolcraft.

The matter was brought up again by David Dale Owen in 1842 in an article entitled Regarding Human Footprints in Solid Limestone, which appeared in the American Journal of Science of that date. Owen here described the appearance of the tracks, and quoted the opinions of Maclure, Troost, Say, and Lesueur to the effect that they were of artificial origin. The English paleontologist, Mantell, was, however, inclined to the opinion of Schoolcraft. Owen himself regarded the tracks as artificial for essentially the same reasons as those advanced by Benton, to the effect that, first, the footprints were not continuous, but isolated; second, this was but a solitary instance of human footprints in solid limestone; third, he could not conceive of the sudden consolidation of compact limestone after having received, while in a plastic state, such impressions; and, last, because of the age, nature, and position of the rock, and because no human remains had hitherto been discovered in any similar formation. He regarded them as having been carved by aborigines with stone implements. In this he was doubtless correct.

Early suggestions of faulting, 1822.

Of interest at this time, as bearing upon the subject of faulting and displacement, is a paper in the American Journal of Science by D. H. Barnes, containing a geological section of the Canaan Mountains in Connecticut, together with observations on the soils of the region. In the explanation of his section, beginning at the bottom, the beds are described as (1) clay loam with bowlders; (2) transition limestone; (3) white quartz, grading on one side into limestone and on the other into clay slate; (4) slate; (5) graywacke slate. The strata then repeat themselves in the same order, the graywacke slate forming the summit of the knob. The entire formation is described as appearing "to have been broken off from the primitive tract on the east of it, and to have sunken down about one thousand feet perpendicularly." Regarding the beds and their associations on Hancock Mountain, he concluded that the strata on the top of the mountains might be considered as originally parts of the same bed now at the base of Canaan Mountain, whence they had "been disrupted by some mighty force," the eastern part remaining firm, while the western settled down to its present position. Referring to Maclure's map, he found that the two formations discussed "butt against each other in a line nearly straight for more than 300 miles." This he accounted for by supposing "that some mighty convulsion has rent asunder the continent from the St. Lawrence to the ocean," though what this force may have been he left for others to decide. He, however, thought it probable that it operated from beneath, "and that, after it had opened for itself a vent, and escaped through the rift caused by its action, the rock strata of the western part fell into the cavity which had previously contained the imprisoned agent."

In 1823 Dr. John J. Bigsby, a surgeon of the British army stationed in Canada, read before the Geological Society of London a paper, subsequently published in their transactions, on the Geology and Geography of Lake Huron. He noted that the rocks of the north shore of the lake were mainly primitive—granite, gneiss, basanite—quartz rock, conglomerate, and greenstone. The other shores were described as occupied by secondary rocks, frequently fossiliferous, which he regarded as forming part of an immense basin, which, "extending probably without interruption from the southern shore of Lake Winnipeg, spreads itself over the greater part of lakes Superior, Huron, and Simcoe, the whole of lakes Michigan, Erie, and Ontario, much of the western part of the State of New York, the whole of the States of Ohio, Illinois, Indiana, and Michigan, and the rest of the valley of the Mississippi." On Thessalon Island was found a new species of *Orthoceratite*, which, though described and figured, was not named. Drummond Island yielded also corals and a trilobite—*Asaphus platycephalus*. Naturally no attempt was made to determine the relative age of the rocks by means of these fossils.

Bigsby's Work in Canada, 1823.

In the year following, Doctor Bigsby had an article in the Annals of the Lyceum of Natural History (New York) on the geology of Montreal. He described the lowest rock of the region as a trap of a kind unique in the Canadas, and illustrating "in a beautiful manner the affinity existing between the formation of which it is a member and the primitive class in general."

Bigsby on the Geology of Montreal, 1824.

A horizontal shell limestone of a bluish-black color he noted as forming the floor of the plain surrounding the hill on which the city stands, and through this hill, as a center, the passage in all directions of a large number of trap dikes.

The sandstone of St. Ann's he rightly described as underlying the limestone, and noted the presence of fossil *Lingulæ*, *Terebratulæ*, *Trilobites*, and *Orthoceratites*.

In the consideration of the sands and gravels constituting the so-called alluvial, he followed the trend of opinion of his time, regarding them as products of the vast inland seas which succeeded the deluge.

The coastal plain of the Eastern United States, which up to this time had been studied in detail only by Maclure and H. H. Hayden, was in 1823 made the subject of a special essay by John Finch, then professor of geology and mineralogy in Birmingham, England. This appears to have been the first attempt at a subdivision of the Tertiary deposits and their scientific correlation, and was, beyond question, the most important contribution to the stratigraphy of the region that had thus far appeared.

Finch's Subdivision of the Tertiary, 1823.

From an examination of all available data, as well as from a personal inspection of a part of the area, Finch was led to conclude that this formation, as existing in America, was identical and contemporaneous with the newer Secondary and Tertiary formations of Europe and other countries.

In this same year Finch gave also a short sketch of the geology of the country near Easton, Pennsylvania, his paper being accompanied by a small colored map and catalogue of minerals. According to J. P. Lesley, this was the first paper on the geology of Pennsylvania to appear in the pages of the American Journal of Science.

The paper on the coastal plain, above noted, is by all means the most important of Finch's geological publications, though in the American Journal of Science for 1826 he had a brief "Memoir" (3½ pages) on the red-brown sandstones of the Connecticut Valley and New Jersey, where he expressed the opinion that such should be considered as belonging to the new-red or variegated sandstones of Europe rather than to the old-red, as contended by some. In this he was right.

In 1823, too, Denison Olmsted, "a Connecticut school-teacher," was authorized by the president of the State board of agriculture of North Carolina to make a geological survey of the State. This act is sometimes referred to with sectional pride as being the first survey undertaken under State auspices.[a]

Olmsted's Work in North Carolina, 1823.

Olmsted's first report, a pamphlet of 44 pages, appeared under date of 1824 and was mainly of an economic character, dealing only with the distribution in the State of such substances as graphite, gold, coal, and building stones.

His second report appeared in 1827, but bore on the title-page the date 1825. He naturally dwelt upon the agricultural possibilities of the country and the suitability of its limestones and marls for fertilizing purposes. Some space was devoted to the great slate formation[b]

[a] The work of Eaton in New York in 1824 was the first sufficiently thorough and systematic survey to be dignified as a geological survey, though as this was done under the patronage of Hon. Stephen Van Rensselaer, it can not be considered a public survey. To Massachusetts credit must be given for the first geological survey made at the expense of the State, the same being begun under the direction of Rev. Edward Hitchcock in 1830. (See p. 307.)

[b] Olmsted's great slate formation lies west of and parallel with the freestone coal formation (Triassic) occupying more or less of the counties of Person, Orange, Chatham, Randolph, Montgomery, Cabarrus, Anson, and Mecklenburg and corresponds, therefore, to the Huronian of Kerr and recent workers.

and its included rocks and minerals. He noted that the "whole section of country from the great slate formation to the Blue Ridge" is granitic, containing numerous subordinate formations, such as mica-slate and greenstone, with beds of iron ore, etc., and described with some detail the Natural Wall of Rowan, which was supposed by early observers (see p. 255) to be the work of human hands, but which he rightly ascribed to the natural jointing and decomposition of a basic igneous rock. The "peculiar assemblage of rocks that cross the Dan River at Buckingham" he classed as transition.

In his "conclusion" he remarked that "the rocks are not, as in most other countries, particularly New England, exposed on the surface, but are very generally concealed by a thick covering of clay and sand." This he rightly regarded as having resulted from the decomposition of the rocks themselves, and not due to a deluge of waters, "as might at first be thought."

Olmsted was not primarily an investigator. He himself, as we are informed by his biographer, always regarded it as his more appropriate sphere of effort not so much to cultivate science as to teach and diffuse it. Graduated at Yale in 1813, and for a time employed as tutor there, he in 1817 was appointed to the chair of chemistry in the University of North Carolina. While here he conceived the idea of a State geological and mineralogical survey and laid the plan before the board of internal improvements in 1821, with the offer to himself perform the entire work gratuitously, asking only an appropriation of $100 (to be afterwards renewed or not at the pleasure of the board), to defray his necessary expenses in traveling. This proposition was, however, declined,[a] only to be renewed a year or two later, with the result that in 1823 the assembly authorized the board of agriculture to have such a survey made and appropriated the sum of $250 a year, for a period of four years, to carry it out. The

Sketch of Olmsted.

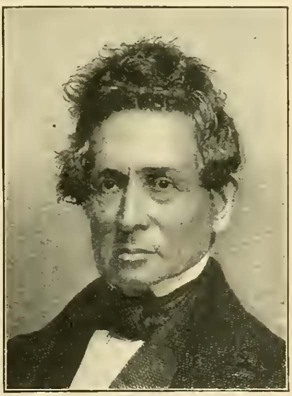


FIG. 15.—Denison Olmsted.

[a] Referring to this failure to secure assistance, Olmsted, under date of January 9, 1822, wrote to a friend: "But the Legislature (the Senate, I mean) has, it seems, saved me any trouble on their account. I, however, feel most highly gratified and greatly encouraged at the handsome manner in which my proposition was treated by the Board of Improvement; and the readiness with which the resolution was adopted by the Commons inspires the hope that something may yet be accomplished at the public expense. But my feelings are too much interested in this project to yield to this failure; I hope to do something by my own exertions next summer, and trust the hospitality of the people of the State will make amends for my poverty. If I can live (as I think I can) on the charity of the people, I don't know what need I shall have of the public money; for Mr. M——— says he will lend me a horse."

work thus inaugurated was interrupted in 1825 by his call to the professorship of mathematics and natural philosophy in Yale College, but was taken up again almost immediately by Dr. Elisha Mitchell and continued for two years longer (see p. 285).

The mental breadth of Olmsted is shown in the fact that while occupying this position at Yale he prepared in 1831 a two-volume work on natural philosophy, a text-book on astronomy in 1839, and became well known throughout the scientific world through his papers on meteoric showers and the zodiacal light.

Of his personal character it is written:

> His uniform kindness and courtesy of demeanor and patience in imparting instruction, the excellent moral influence which he always exerted, as well by his consistent Christian example as by his personal counsels, the genuine friendliness of his disposition, and the unaffected interest which he always manifested in the welfare of his pupils—especially the readiness and fidelity with which he encouraged and assisted any who exhibited special fondness for the studies of his department—will not soon be forgotten by those who enjoyed the benefit of his instructions, and especially by those who were admitted to his closer friendship.

Hitchcock's Geology of the Region Contiguous to the Connecticut River, 1823.

In this same year Edward Hitchcock published in the American Journal of Science a sketch of the geology, mineralogy, and scenery of the regions contiguous to the Connecticut River, the same being accompanied by a colored geological map embracing an area some 30 miles broad by 150 miles in length. The coloring and classification of the rocks were not strictly Wernerian, as might have been expected, but an attempt was made "to give every particular rock that position and extent on the map which it actually occupies on the earth's surface." The paper was devoted mainly to a discussion of the lithological nature and geographic distribution of the various rocks, which were classed as granite, gneiss, hornblende slate, mica slate, talcose slate, chlorite, syenite, primitive green slate, argillite, limestone, verd-antique, old-red sandstone, secondary greenstone, coal formation, and alluvion. Incidentally he discussed their possible origin and relationship.

The granite he described as occurring in beds, and regarded it as primitive, along with the gneiss, mica slate, and the greenstone to the west of New Haven, while that to the north and east was thought to be secondary. The argillite was also regarded as primitive, on the ground of its being highly inclined and destitute of organic remains. The red-brown sandstone now known to be of Triassic age he considered as the old-red sandstone of Werner and Cleaveland, but discussed the possibility of a part of it, as at Chatham and Middletown, belonging to the coal formation.

He chronicled the finding in this sandstone at Deerfield of petrifactions belonging to the genus *phytolite* and to the species *lignite*, and agreeing with the petrifactions found in the Catskill red sandstones by Eaton and referred to "the tribe of Naked Vermes." Fossil bones of an animal some 5 feet in length were also mentioned as having been found in this sandstone at East Windsor.[a]

The year following Prof. Chester Dewey came forward with a paper in the same journal, A Sketch of the Geology and the Mineralogy of the Western Part of Massachusetts. This was likewise accompanied by a hand-colored geological map designed as a continuation of Hitchcock's and carrying the field of observation as far west as the Hudson River.

Dewey on the Geology of Western Massachusetts, 1824.

Working from the Hudson River eastward, he found a belt of transition argillite succeeded by a broad belt of graywacke with included areas of the argillite; this followed by another continuous belt of the same, and then one of transition limestone and a narrow one of primitive argillaceous slate directly along the border line of New York and Massachusetts. Beyond this, in Massachusetts, a broad belt of primitive limestone with included areas of mica slate, quartz rock, and transition shell and compact limestone, which still farther to the east became the predominant rock, with a narrow area of gneiss, a small one of granite, and one of talcose slate.

The most pretentious piece of fieldwork accomplished by Amos Eaton was that done under the direction of the Hon. Stephen Van Rensselaer in 1824, and comprised a geological and agricultural survey of the district adjoining the Erie Canal. The results of this survey were published in a quarto volume of 163 pages, which was accompanied by a geological section extending from Albany to Lake Erie, and one by Edward Hitchcock from Boston to Plainfield, the two combined enabling Eaton to give a continuous section all the way from Lake Erie to the Atlantic Ocean at Boston Harbor.

Eaton's Survey of the Erie Canal, 1824.

To judge from the introductory remarks in this report, Eaton had been accused of a disposition to create new names. He, therefore, here announced that he had made use of European names, so far as possible, but had found at least five distinct and continuous strata, none of which could, with any propriety, take a name given in any European treatise which had thus far reached this country.

He found along the line of the canal rocks belonging to the primitive, transition, and secondary series. All these were described in considerable detail, but almost wholly with reference to their lithological features. When fossils occurred, such were noted, but were not utilized as aids to correlation.

The prevalent ideas on chemical geology are well brought out in certain parts of his discussion. He recognized the fact that many of the valleys were excavated in the softer and more soluble rocks, like

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[a] These bones were at first thought to be possibly human, but the finding of evidences of a tail at least 5 feet in length caused the abandonment of this idea! (American Journal of Science, III, 1821, p. 247.)

limestone, and that carbonic acid holds its base (the lime) with a tenure more feeble than that of the common acids: consequently he argued that when muriatic, sulphuric, or nitric acid comes in contact with limestone, it is immediately decomposed.

We have vast quantities of muriate of lime in our wells, springs, etc., which is a very soluble salt. If nature has now, or formerly had, any method for presenting large quantities of muriatic acid to the lime rocks, they would of course be reduced to that soluble salt with great rapidity. Lime rocks would be rapidly dissolved, leaving valleys between those rocks which are subject to the ordinary disintegrating agents only. The valleys of Adams, Williamstown, Little Hoosick, etc., which are situated on limestone, could then be satisfactorily explained. If the common opinion that the ocean has stood over our continent be received as true, we have only to add one more conjecture to make out the requisite supply of muriatic acid; that is, we must suppose that the ocean at that time contained an excess of that acid.

In spite of admonitions by Van Rensselaer, Eaton insisted in indulging in a theorizing propensity, although he would not acknowledge it by this name, claiming that he but traced "a few of nature's footsteps where the impressions still remain entire." Finding large and small masses of what he designated as calciferous sandstone, metalliferous limestone, and graywacke, which properly overlie the slate, actually, as he thought, embedded in it, where the rocks were exposed, as at Cohoes Falls, he would argue that these masses fell in between the slate laminæ while the latter were in a semi-indurated state.

Eaton noted the probable difference in age between the red sandstones of the Connecticut Valley and of the Catskill Mountains, which latter he rightly considered to belong to the old-red or Devonian formations. In discussing the Saliferous rock occurring near Little Falls and extending to the west end of Lake Ontario in upper Canada, and its economic importance, he was disposed to argue that the brine springs issuing from the same were what he called "the daily productions of nature's laboratory." "We see," he wrote, "the sulphur in iron pyrites taking oxygen from water, and thereby becoming sulphuric acid; we then see it uniting with magnesia, which is diffused in rocks, and thus forming Epsom salts. * * * We are all familiar, too, with the process of nature by which alum and copperas are made. Why may we not suppose that the two constituents of common salt (muriatic acid and soda) are in some state of combination in the rocks of the salt district, and that by some of those double decompositions with which nature is perfectly familiar salt is produced in the liquid state? May not this be the cause of the superior saltness of the brine springs of Salina over those foreign springs which are supposed to proceed from the solution of rock salt?"

It was in this work that Eaton introduced the name "Calciferous slate" to designate the slaty rock associated with gypsum and shell limestone occurring as the principal rock forming the ridge south of the land from Oneida Creek to Pittsford.[a]

The naturalist Rafinesque, as might have been expected, did not hesitate to express himself on subjects geological, his ideas, however, being a strange admixture of Wernerism and groundless imagery.

Views of Rafinesque, 1824.

We will note here only his Annals of Kentucky, which appeared in Humphry's history of that State, published in 1824, where, as Doctor Peters has succinctly remarked, "In only 26 duodecimo pages he gives the geological, ethnological, and historical annals of Kentucky from the first day of creation, according to Moses, down to the current year."

The geological history of the State he divided into six periods, the first being that of a general inundation, in which the "briny ocean covers the whole land of Kentucky and the United States, rising above 4,000 feet over the Cumberland or Sawioto Mountains and 5,000 feet over the limestone region near Lexington." The Organ and Mexican mountains alone in all North America rose above the water level.

Through a gradual decrease of the ocean and the decomposition and consolidation of its waters the various rock strata were deposited in the following order: (1) Limestone; (2) slate; (3) sandstone; (4) freestone; (5) grit; (6) pebblestone. These, he stated, were not always superincumbent or coexistent, though generally horizontal except the last four toward the Cumberland Mountains, which, having probably a granitic nucleus, have compelled the incumbent strata to become "obliqual" or inclined from ten to thirty degrees. (In this, it will be noted, he showed an inability, characteristic in his day, to com-

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[a] The following reference to this survey appeared in the American Journal of Science, IX, 1825, and will serve to show how Eaton's work was regarded by his contemporaries. The note, it should be stated, was signed C. D. (presumably Chester Dewey):

"Mr. Jeffrey, the principal conductor of the Edinburgh Review, has obtained the opinion of Professor Buckland, the celebrated author of the *Reliquiæ Diluvianæ* (published in 1823), on the above work of Professor Eaton. In a letter to the Hon. S. Van Rensselaer Mr. Jeffrey has given the result. Mr. Buckland says that the 'author seems both to understand his subject and to have done his work carefully.' The work contains, indeed, abundant evidence of extensive and patient examination. This point will not be affected by the adoption or rejection of Mr. Eaton's peculiar views by our geologists. In some parts there is an evident improvement upon some of his previous publications on the geology of our country. Thus, at page 31 and page 62 and onward we find introduced 'primitive argillite,' a rock so clearly separated and so easily distinguished in our country from 'transition argillite,' though both are united under the same name by Bakewell and some others.

"Mr. Buckland makes some objection to the *style*, and complains of Mr. Eaton for 'affecting some needless novelties in technical language.' However true this charge may be, the censure is feeble when compared with the commendation contained in the previous quotation. In our country the work has been censured for this fault, and more particularly for the introduction of rocks or localities which do not belong to the district which is described. In this way unity is not preserved, prehend the effect of subsequent uplift in tilting rock strata.) By the operation of submarine volcanoes during this period the strata of coal, clay, and amygdaloid were formed and intermixed at various intermittent times with the other strata.

During the second period the Cumberland Mountains emerged from the sea, the waters of which sank to a level of 1,500 feet above those of to-day. The formation of the schistose rocks proceeded, vegetation began, and streams began to flow.

During the third period the level of the water was reduced to 1,100 feet and all the table-lands and highlands of Kentucky became uncovered. An inland sea still covered the Ohio limestone basin, extending from the actual mouth of Sciota River to that of Salt River. Land animals, insects, reptiles, birds, and quadrupeds were created during this period.

During the fourth period the level of the sea was reduced to 700 feet, and the limestone sea of Kentucky drained. Alluviums and bottoms began to form in the valleys and gulfs by the attrition of the strata and soil conveyed and deposited by the streams. Sinks and caves in the limestone region were formed. Lastly, Adam appeared in the Garden of Eden. This fourth period of Kentucky history thereby answered to the sixth day of the general creation.

The fifth period was that of Noah's flood, though Rafinesque acknowledged he failed to find any traces of such a violent convulsion in Kentucky. The ocean, which still bathed its western corner, subsided to about 300 feet above its present level and abandoned Ken-

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and the continuity of the description is much interrupted. We do not object to this in that part of the work entitled 'General Descriptions of North American Rocks,' though some have said that these can hardly belong, in a general view, to the district of the canal. But in the 'Description of rocks in the vicinity of the Erie Canal,' page 47, the fault often occurs. We mention the account of the hornblende rocks near West Point, page 54; of granular quartz, pages 56, 57; of granular limestone, pages 57, 58, and many others which are not found near the line of the canal.

"If the work should pass to a second edition, which is highly probable, and even rendered somewhat necessary to make it as complete as the subsequent examinations of Professor Eaton enable him to do, and as the light thrown on the subject of the newer formations by the very able work of Conybeare and Phillips on the Geology of England and Wales seems to require, we would suggest as an *improvement* of the work that the notices of rocks which are not found along the line of the canal be omitted in this part of the work, or be reduced to the bare remark that they do not occur in the district, and that the remarks and localities of rocks in other parts of the country be taken from the text and put into form of notes. In this way the continuity of geological description of the country along the canal will be unbroken. We think no one can read the work without being sensible of its interest and importance to every one who examines the rocks of this district. The localities are given with much precision, and the traveler is enabled at once to ascertain the rocks intended by the names which Professor E. has given them. It were to be wished that the common nomenclature of the rocks had been altered with a more sparing hand."

tucky forever. Strata began to consolidate, ponds and marshes decreased, animals multiplied, and vegetation overspread the soil.

The sixth period, that of Peleg's flood, was one of catastrophe. Great volcanic eruptions in Europe and America, with awful earthquakes convulsed the Atlantic Ocean. During this period the Atlantic land disappeared leaving only the volcanic islands—Azores, Madeira, Canary, and Cape Verde—to mark its position.

It will be remembered that in 1793 Benjamin De Witt noted the great diversity among the bowlders along the shore of Lake Ontario and recognized the fact that such must have been conveyed there by some extraordinary means. The means conceived of by De Witt were indeed extraordinary and nothing less than a "mighty convulsion of nature." Peter Dobson, a Connecticut cotton manufacturer, writing thirty-two years later, showed himself a better observer and more gifted in powers of deduction.

Dobson's Observation on the Drift, 1825.

In a letter to Benjamin Silliman, dated November 21, 1825,[a] Dobson described bowlders which were unearthed at Vernon, Connecticut, while excavating preliminary to the erection of a cotton factory, as "worn smooth on their under side as if done by their having been dragged over rocks and gravelly earth in one steady position." They also showed scratches and furrows on the abraded parts. He could account for these appearances only by calling in the aid of ice along with water, the blocks having been worn by being suspended and carried in ice over rocks and earth under water.

These observations seem to have attracted no attention at the time, and even Edward Hitchcock, thirteen years later, attached no serious importance to them, although his attention was called to the matter by another letter from Dobson, this time addressed to Hitchcock himself. In this second letter, written in 1838, Dobson described the bowlders as having been first rounded by attrition and then worn flat on one side by a motion that kept them in one relative position, as a plane slides over a board in the act of planing. Some of them he describes as worn and scratched so plainly that there was no difficulty in pointing out which side was foremost in the act of wearing, a projecting bit of quartz or feldspar protecting the softer material behind it. In this letter he again announced his inability to account for these appearances except on the supposition that the boulders had been enveloped in ice and moved forward over the sea bottom by currents of water. The drifting icebergs off the Labrador coast he thought might well illustrate the conditions and methods of their production.

Perhaps it may have been because Dobson was a cotton manufacturer and not a member of the learned profession, or there may have

[a] This may be found in American Journal of Science, X, 1826.

been other reasons for it, but Hitchcock allowed the observations to pass unnoticed until 1842 when the subject was brought up by no less an authority than Murchison, in his anniversary address before the Geological Society of London. "I take leave of the glacial theory," said Murchison, "in congratulating American science in having possessed the original author of the best glacial theory, though his name has escaped notice, and in recommending to you the terse argument of Peter Dobson, a previous acquaintance with which might have saved volumes of disputation on both sides of the Atlantic."[a] Supported by this somewhat enthusiastic indorsement, Hitchcock then gave the letter to the public through the American Journal of Science,[b] though at the same time remarking that he had himself derived his ideas concerning the joint action of ice and water from the writings of Sir James Hall.

The Long-Keating Expedition, 1823-1825.

April 25, 1823, Maj. S. H. Long received orders from the War Department to make an expedition for a general survey of the country in the vicinity of the Great Lakes and the sources of the Mississippi; to prepare a topographic description of the same; to ascertain the latitude and longitude of all the remarkable points; to investigate its productions, animal, vegetable, and mineral, and to inquire into the characteristics and customs of the Indians. The route of the expedition (see map, fig. 16) beginning at Philadelphia, was through Wheeling, West Virginia, to Chicago by way of Fort Wayne; thence to Fort Crawford and up the Mississippi to Fort St. Anthony, and the source of the St. Peters River; thence to the point of intersection between Red River and the forty-ninth degree of north latitude; along the northern boundary of the United States to Lake Superior, and thence homeward by the Great Lakes.

Although not intended primarily as a scientific survey, it was accompanied by Thomas Say, zoologist, and William H. Keating, mineralogist. It was expected that Dr. Edwin James, who with Say had been a member of the expedition of 1819–20, would be a member of this also, but through failure to connect with the party at Wheeling or Columbus the expedition was deprived of his services.

An account of this survey, under the title of Narrative of an Expedition to the Sources of St. Peters River, etc., was prepared by William H. Keating and published in two volumes in London in 1825. Keating, it should be noted, was professor of mineralogy and chemistry as applied to the arts in the University of Pennsylvania, and though his published notes contain little or nothing along the broad lines of geology, they are full of references which, at the time they were written, were of value.

[a] Anniversary address, Proceedings of the Geological Society of London, 1842.
[b] Volume XLVI, 1844.

He remarked on the disappearance of the primitive rocks soon after leaving Philadelphia and the appearance of the transition limestone,

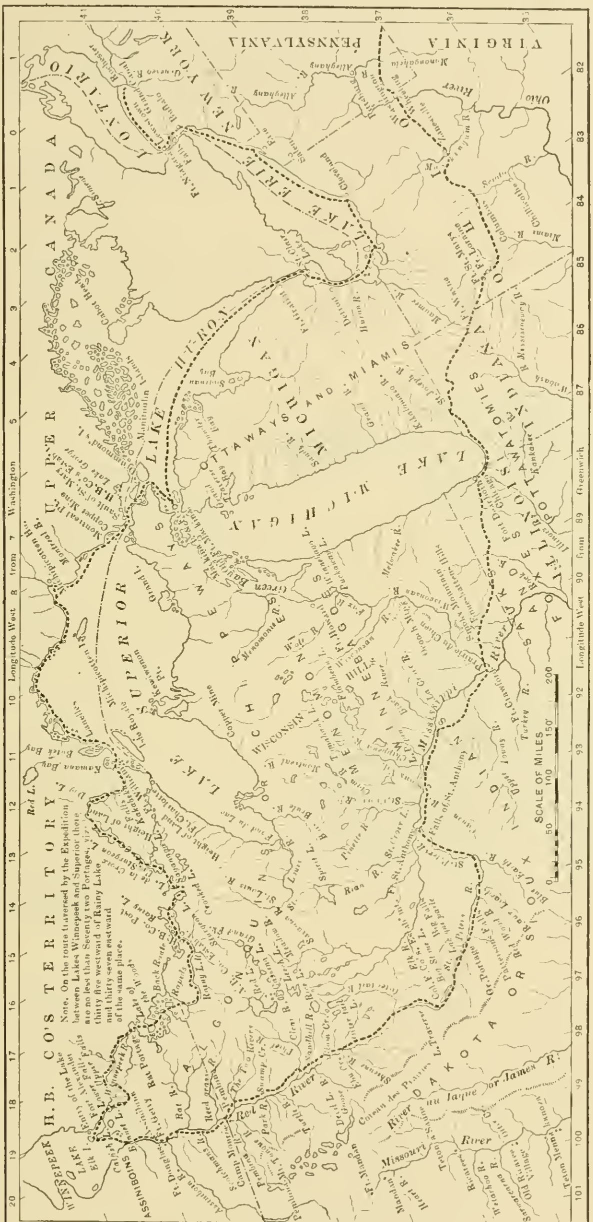


FIG. 16.—Map showing Routes of Long's Expedition of 1823.

with occasional protrusions through this limestone of amphibolite. He also made reference to the red sandstone of Pennsylvania, New Jersey, and Maryland and the calcareous breccia found on the Potomac

River. The occurrence of a white marble near Hagerstown and a secondary blue limestone in the vicinity of Cumberland was noted, and some attention given to the coal formations in the vicinity of Cumberland and Wheeling. He noted further the occurrence of a limestone containing organic remains lying in a nearly horizontal position in the vicinity of Chicago, but no superposition being visible, he was unable to determine its relative age.

Concerning the lead ores at Dubuque, and their apparent occurrence only in the alluvial soil, he wrote:

From the specimens which we have seen, * * * we can not hesitate in asserting it as our opinion that no lead has yet been discovered on the Merrimeg or Mississippi in metalliferous limestones, but that wherever it has been found it has always been in an alluvium and never in regular veins or beds, nor even in masses which might be considered as coeval with the substances in which they are embedded.

The Cambrian sandstone found between the Wassemon and the Wisconsin rivers he regarded as not older than the variegated or *Bunter sandstein* of Werner (Triassic), and the Lower Silurian limestone which lies above the sandstone, as corresponding to the English Lias. The whole region comprising the headwaters of the Winnipeek River was looked upon as having been at a comparatively recent period an immense lake interspersed with innumerable barren, rocky islands, which had been drained by the bursting of the barriers which tided back the waters. The innumerable bowlders which he found covering the valley were regarded, as were similar bowlders in other places by his contemporaries, as due to the flood of waters caused by the bursting of these natural dams.

This was plainly a recognition of the extinct glacial Lake Agassiz, later described by Lieut. G. K. Warren,[a] and the history of which was worked out in detail by Warren Upham.

Keating's ideas as to the possible development of the mining industry were not of the most advanced type. Referring to the subject of the supposed source of the native copper reported by Schoolcraft (p. 244), he wrote:

The question which appears to us of far greater importance is not where the copper lies, but what shall we do with it if it should be found. We are very doubtful whether any other advantage would result from it, at least for a century to come, than the mere addition in books of science of a new locality of this metal.

This in 1825! The development of the Michigan copper mines began about 1855, and up to 1889 the combined mines had produced over 1,000,000,000 pounds of the refined metal. The output for 1889 alone amounted to 87,455,675 pounds.

In a Notice of Snake Hill and Saratoga Lake and its Environs, by Dr. J. H. Steel, in the American Journal of Science for this same

[a] American Journal of Science, XVI, 1878, p. 417.

year, is figured and described what is evidently an overturned fold. This is of interest, since while the nature of the fold was partially realized, the means by which it was brought about was considered as problematical. Similar phenomena had been noted by Eaton (p. 253) and by Maclure, but with nothing like as much detail. The writer says:

J. H. Steel on Overturned Folds. 1825.

> It is impossible to examine this locality without being strongly impressed with the belief that the position which the strata here assume could not have been effected in any other way than by a power operating from beneath upward and at the same time possessing a progressive force, something analogous to what takes place in the breaking up of the ice of large rivers. The continued swelling of the stream first overcomes the resistance of its frozen surface, and having elevated it to a certain extent, it is forced into a vertical position, or thrown over upon the unbroken stratum behind, by the progressive power of the current.
>
> If it can be admitted that the operation of such a power did produce the effect here represented, it must have taken place before the materials of which the formation is composed had passed into an indurated state, as most of the strata remain unbroken, and, where the argillite has crumbled away, the curved part of the graywacke may be taken out entire, and some of them, which I now have in my possession, exhibit indentations and protuberances, particularly on their curved surfaces, evidently the result of friction while in a plastic state.

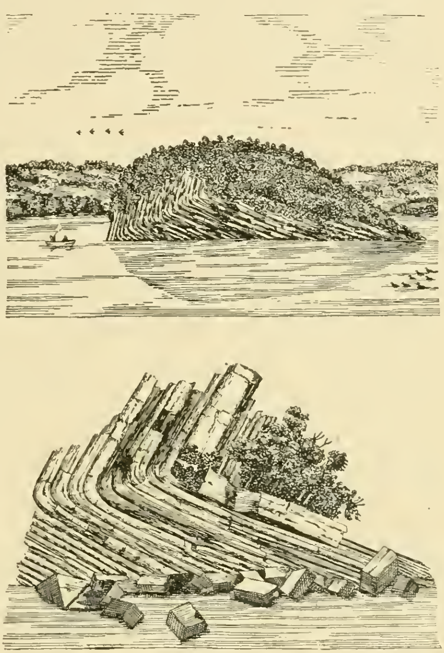


Fig. 17.—Sections of Snake Hill, Saratoga Lake. (After J. H. Steel.)

The description is of still further interest historically, when considered in connection with the dispute relating to priority of discovery which later arose between Messrs. Hitchcock and Rogers. (See p. 314.)

The fact that rock strata were not always found lying even approximately horizontal had been often noted, but no rational explanation suggested or, indeed, attempted. In that year, however, Maclure, in noting the fact that the Transition rocks dip, suggested the possibility of its being caused by their having been "disposed on the primitive, concerning which we can as yet scarce conjecture anything."

Inclined Strata and Overturned Folds. 1825.

The appearance in book form of Prof. Jeremiah Van Rensselaer's lectures on geology, as delivered before the New York Athenæum in 1825, gives us an opportunity of judging of the condition of science at that date, such as was offered a few years earlier by Mitchill's Observations.

Van Rensselaer's Lectures on Geology, 1825.

Van Rensselaer was not so much an original investigator as a student and teacher; hence the inference is fair that his work gives us a summary of existing knowledge rather than the details of his own observations or his individual views. He reviewed the opinions of the cosmogonists and theorists from Burnett, in 1680, down to Werner and Hutton, and referred to the work of his predecessors and contemporaries in America, summing up with conclusions condensed from Cuvier's Observations, to the effect that, first, the sea had, at one period or other, not only covered all our plains, but remained there for a long time in a state of tranquillity; second, that there had been at least one change in the basin of the sea which preceded the present one; third, that the particular portions of the earth which the sea had abandoned by its last retreat had been laid dry once before and had at that time produced quadrupeds, birds, plants, and all kinds of terrestrial productions; and that it had been reinundated by the sea, which had since retired and left it to the possession of its own proper inhabitants. These facts, which had been proven through geological evidence, he regarded as supporting the accounts of Moses, both agreeing, first, in the prevalence over everything else of water at the time of the creation; second, in the subsequent separation of the land from the water; and, third, in the eruption of the sea over the continent, the last corresponding to the Noachian deluge.

Van Rensselaer recognized the value of fossils in proving the identity of geological horizons, also the fact that organic remains have been deposited in successive generations and in such order that those of one bed bear a certain connection to each other and exhibit certain distinctive points differentiating them from those of earlier or later deposits, and that the greater the distance between the deposits the greater the difference between the contained fossils. This, I believe, is the second recognition by an American author of a now well-established principle.

The tendency to make sweeping generalizations founded upon purely local observations is noticeable in his writings, as in those of many of his contemporaries. Thus, in describing the gneiss:

> It is the next rock to granite and occurs resting or lying upon it. When they are both seen in the same mountain its ledge is always the lower of the two. Mountains of gneiss are seldom so steep as those of granite, and the summits are not quite so peaked.

Or, again, in writing on the weathering of rocks:

The decomposition of granite is slow and when decomposed the unfriendly siliceous grains are easily washed away. There is neither vegetable nor animal matter in the compound; it does not absorb moisture, letting the moisture percolate, nor does it retain heat. The soil made from gneiss is not washed away so easily, and the mica yields more argillaceous matter. * * * Micaceous schist and argillite decompose more rapidly and form a better, though not a good, soil. * * * The rivers of primary districts have rocky beds and precipitous banks, etc.

Van Rensselaer was one of the first to recognize the necessity of exercising care in the selection of stones for building purposes:

We take our materials because they are near at hand, because they are cheap, and because others have taken the same, in preference to searching out others which * * * are more durable. Scarcely any one building in Europe or America of modern construction at the end of one thousand years will have one stone left upon another stone to denote the place where it stood, and the most splendid works of modern architecture are even now hastening to decay from want of attention to this subject.

His remarks on anthracite coal offer an interesting illustration of a disposition, still too frequently met with, to make the observed facts conform to preconceived opinions. Anthracite or native mineral carbon, or "blind coal," he wrote, is not regarded, strictly speaking, as a coal, though combustible.

It occurs in the primary rocks, and hence it is obvious that it did not proceed from the decomposition of vegetable substances, since it is generally acknowledged that the primary rocks were formed previous to the existence of vegetation.

An analytical key or a synopsis, given with a view of facilitating the study of geology, is of particular interest, since the methods of modern petrography have shown how absolutely impossible it is to classify rocks by a simple examination of the hand specimen and without the aid of a microscope. It is difficult to imagine a student in other than a thorough state of mental demoralization who should attempt to identify and classify rocks from such a description, an abstract of which is given below:

SYNOPSIS OF THE OVERLYING OR SUPERINCUMBENT ROCKS.

FIRST DIVISION.

Simple, or apparently so.

A. Wacke, of the German school. Resembles indurated clay, with an even and smooth earthy, or an uneven, somewhat granular fracture, and a shining streak.

a. Compact.

b. Cellular; but generally in that case partly amygdaloidal and appertaining to another division.

B. Indurated clay, more or less hard, with an earthy and dull fracture.

a. Compact.

This is different from the ferruginous clays found often with the trap rocks, which pass into jasper.

b. Cellular.

Like var. A, *b*, it is rarely cellular in large masses without also containing amygdaloidal nodules, when it passes to another division. The colors of this variety are usually ash or gray of different hues, or modifications of red, or brown, or purplish black.

The prevalent ideas on the subject of earthquakes at this time may be gleaned from a paper by Dr. Isaac Lea, of Philadelphia, in the American Journal of Science for 1825. Lea rejected the theories put forward in 1749 by a Doctor Stukley to the effect that earthquakes were caused by lightning, but regarded them as the effect of volcanic eruptions, though at the same time he could see no necessary connection between the electric discharges of volcanoes and the earthquakes, regarding such as an effect rather than a cause.

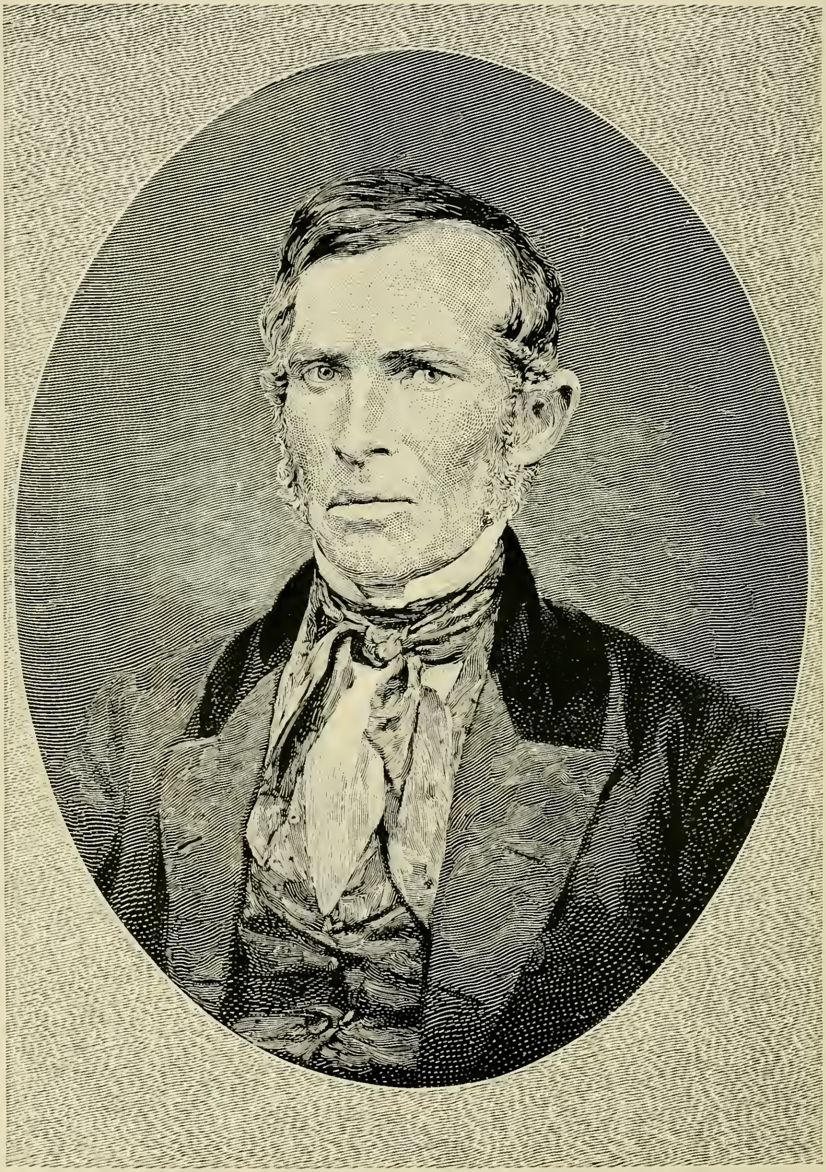
Isaac Lea on Earthquakes, 1825.

He thought that there were strong reasons for believing a considerable portion of the interior of the earth to be in a constant state of incandescence and that there were beneath the surface great cavities or channels of connection between one volcano and another. "We must admit," he wrote, "of deep-seated channels of connection stretching from one portion of the globe to the others, through which the explosive gases pass with an instantaneous motion, accompanied by a rumbling or terrible noise peculiar to earthquakes." In this, it will be noted, he followed to a large extent the teachings of Humboldt and Newton. These channels, he thought, had connection with the sea, basing his opinion upon the fact that volcanoes throw up salt water and fish; moreover, that most volcanoes are situated near the sea. He regarded these branching channels as species of horizontal volcanoes, their roofs and walls furnishing material which, aided by oxygen supplied by the influx of the sea, would yield the necessary amount of combustible matter to keep up the earth's internal fire. To the possible objection that rocks in themselves would not burn, he answered that, when such are decomposed, "their metallic bases, calcium, silicium, aluminum, magnesium, etc., are highly incandescent."

Four years later (1829) Maclure, in discussing the theories of Poulett Scrope, took exception to the views of Lea, though he failed to offer anything satisfactory in return. He instanced the earthquake of 1811–12 in the Mississippi Valley, in which only the alluvial formations had been disturbed, and questioned if such could not have been caused by the evolution of elastic gases arising from the fermentation of large masses of vegetable matter accumulated in the beds. If such were the case, however, he recognized the possibility of an increase in the frequency of earthquakes as fermentation went on. Maclure evidently did not place a great amount of reliance on his own theories, for he states, in referring to some of the ideas advanced by Scrope:[a] "All these speculations are

Maclure's Criticisms of Scrope and Lea, 1829.

[a] Scrope's Theory of Volcanoes appeared in 1825.



EBENEZER EMMONS.

State Geologist of North Carolina.

out of the reach of our senses and can be accounted only as amusement" for the present.

In 1826 there appeared a Manual of Mineralogy and Geology, designed for the use of schools and for persons attending lectures on these subjects, as also a convenient pocket companion for travelers in the United States of America, the same being from the pen of Dr. Ebenezer Emmons, destined later to act a very important part in American geological history, but at that time newly graduated from the Rensselaer Polytechnic Institute at Troy, New York.

Emmons's Manual of Mineralogy and Geology, 1826.

Emmons at first studied, and later practiced, medicine, but in 1828 removed to Williamstown, where he had been appointed lecturer on chemistry. During the years 1830–1837 he also served as junior professor in the Rensselaer Institute, and in 1836 was appointed one of the four geologists of the New York State survey. In 1842 he became custodian of the State collections at Albany, and in 1843 engaged in investigations relating to the agricultural resources of the State, the results of which were published during the period 1846–1854 in the form of five quarto volumes. In 1851 he was appointed State geologist of North Carolina, a position which he retained until the time of his death.

As noted elsewhere, Emmons, during his work on the New York State survey, became involved in a discussion relative to the so-called "Taconic System," which lasted for nearly half a century and which undoubtedly seriously embittered the latter days of his life. The dispute, indeed, became at times so harsh that Emmons was practically ostracized by the scientific fraternity.

In 1851 he published a pretentious volume on North American geology, and, in connection with his work in North Carolina, two volumes on the agriculture and geology of the State. He died during the period of the civil war, and his papers and notes are said to have become lost in the unsettled condition of the country which followed.

It is impossible here to go into a discussion of the true merits of the Taconic controversy, and the matter is reserved for a separate chapter. Hundreds of pages of printed matter have been published, covering a period of nearly fifty years, but the name has now disappeared from the maps and is only of historical interest.

Emmons's Manual, to which reference is above made, and which, as stated in the title page, was adopted as a text-book at the Rensselaer school at Troy, was a small duodecimo volume of 230 pages. It had the distinction, so far as the mineralogical part was concerned, of being the second treatise of its kind written by an American and for American students, being preceded only by Cleaveland's Mineralogy, published in 1816. In geology it was preceded by the works of Cleaveland in 1816 and Eaton in 1818.

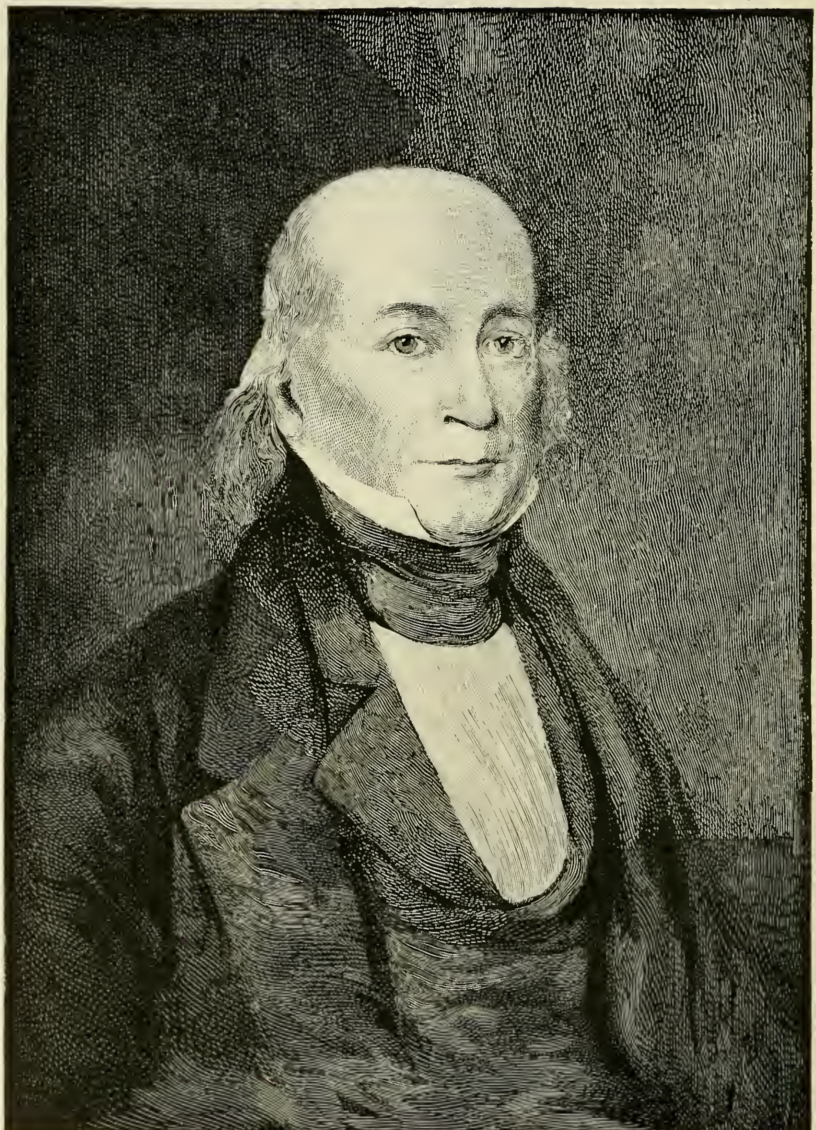
In Emmons's work the minerals were all included in four classes, with an appendix which contained those minerals of which but little is known. The classes were subdivided, as Cleaveland and others had done before him, into orders, the orders again into genera, and the genera finally into species. His arrangement of classes was, however, somewhat different from any of his predecessors. Thus, the first class included those minerals, not metallic, which are oxidable or which are compounds whose bases are oxidable. It comprised native gases and liquids, sulphur and carbon, and the carbon compounds, but, singularly enough, no mention was made of graphite.

The second class included all minerals which are metallic or whose bases are metallic; the third class all those which consist of an alkaline or earthy base in combination with acids, and the fourth those which consist of an earth or are compounds of earths with variable portions of alkaline and metallic oxides. In the seven sections into which this last class was divided he placed quartz in all its varieties, siliceous slate, pumice, obsidian, clinkstone, a large number of hydrous and anhydrous silicates, argillite, wacke, clay, phosphates, etc. But little attention was given to crystallography, and "silex, alumnie, and lime are considered as the oldest of the earths, as they enter into the composition of the primitive rocks." Altogether 297 species were recognized, 44 of which were mentioned in the appendix as little known. Many of these, such as pumice, obsidian, wacke, etc., can not, of course, be properly considered as minerals. In spite of this unintentional exaggeration, it is interesting, for purposes of comparison, to note that in the latest edition of Dana's Mineralogy (1892) 824 species were recognized.

The part of Emmons's work devoted to geology was made up mainly of a "general description of North American rocks." The classification adopted was the same as that used by Eaton and need not be noted here further than to say that he included an argillite among his primitive as well as transition rocks, while Eaton limited argillite to the transition series, though recognizing the possibility of a primitive form.

Among the early workers in stratigraphic geology, along lines laid down by Cuvier, Brongniart, and their successors, mention must be made of Gerard Troost, born in Holland in 1776 and dying in Nashville, Tennessee, in 1850. Like many naturalists of his time Troost was a physician. He studied in France; was appointed by the King of Holland to accompany, in a scientific capacity, a naval expedition to Japan. He was captured and imprisoned by English privateers, finally returning to Paris. He thence took passage for New York in an American vessel and was again captured, this time by a French privateer, and once more imprisoned. On his release he went again to Paris, was again allowed to embark, and in 1810 came to Philadelphia.

Troost and His Work, 1826.



GERARD TROOST.

State Geologist of Tennessee.

When the Philadelphia Academy of Sciences was established in 1812 he became its first president, holding the office for five years, when he was succeeded by William Maclure. Troost, with Owen, Maclure, and others, joined the communistic society at New Harmony, Indiana, in 1825, but removed to Nashville, Tennessee, in 1827, and the following year was elected professor of chemistry, geology, and mineralogy in the university of that city. In 1831 he became State geologist, holding the office till 1839, when it was abolished. Nine reports were made during his time, but seven of which were published. Prior to going to Tennessee his most important geological work was a survey of the region about Philadelphia, the same being done and the results published in 1826 under the patronage of the Society for the Promotion of Agriculture.

The work comprised forty small octavo pages with a colored map of the region included within a half circle north of the Delaware River, having a radius extending a little beyond Chester, i. e., some 17½ miles. As may be readily supposed, fully three-fourths the area was colored as gneiss, with narrower bands extending in a general way parallel with the river; in the northern part, of primitive clay-slate and of limestone. Between the gneiss and clay-slate was a short, narrow belt of serpentine, and between the clay-slate and limestone one of eurite, and in the extreme northeastern portion of the sheet a band of transition graywacke. Among the varieties of rocks mentioned, in addition to those enumerated and comprising subordinate formations, are diabase and pegmatite. The eurite was described as occurring north of the high ridge which separates the limestone from the granitic rocks and as being in every respect similar to that of Penig, on the Erzgebirge. "I was delighted," he wrote, "at meeting this rock for the first time on this side of the Atlantic. I imagined myself transported to the Erzgebirge, in Saxony, and remembered with renewed pleasure the father of geology, who made us acquainted with it." More than half of the paper was given up to a discussion of the physical and chemical properties of the soil, as might be expected when its date and the auspices under which the work was done are taken into consideration.

Webster's Account of the Geology about Boston, 1826.

In the Boston Journal of Philosophy for the same year the ill-starred Prof. J. W. Webster gave a somewhat detailed account of the geology of Boston and vicinity, describing the three hills, to which "Boston owes its ancient name and so much of its picturesque beauty," as being composed mainly of hard, compact clay with gravel and bowlders. Amister's Hill was described as composed largely of clay-slate, passing on the north into hornblende slate, the latter containing veins of "greenstone;" and Prospect Hill, in part of a greenish compact feldspar, which passes into clay-slate, covered toward its northwest extremity by a mass of trap. "This hill," he wrote, "exhibits that gentle acclivity and rounded summit so common in the transition formations of the Wernerian school."

The Medford trap (diabase) he noted as being unfit for architectural purposes, owing to its rapid disintegration, a fact which has been many times commented upon in more recent years. The tendency manifested by the "greenstone" as a whole to exfoliate in bowlder forms with concentric structure, he correctly ascribed to weathering, as did Gibson writing several years earlier (p. 254).

He noted the occurrence of abundant joints in the conglomerate of Dorchester, but considered such as inexplicable with the geological information then available. An interesting light is thrown upon the lack of knowledge of the chemical composition of rocks at that time in the continuation of his paper the following year, in which he described this conglomerate—a highly siliceous rock—as passing into the overlying melaphyr, a basic igneous rock. In several places within the town of Brighton he thought to note the transition from one rock type to another.[a]

In the American Journal of Science for 1827 Alanson Nash presented his first, last, and only geological paper that seems to have found its way into print—this relating to the lead mines and veins of Hampshire County, Massachusetts—and offered some interesting speculations as to their origin.

Alanson Nash on Vein Formation, 1827.

That they were not once open fissures filled from above, the fissures themselves being formed by the unequal subsidence of the earth's crust or through shrinkage caused by desiccation, according to the Neptunian theory, was to him evident for the following reasons: If the cavities were formed by desiccation and subsidence the veins would be widest at the surface and narrow as they descend, whereas, in fact, the very reverse is the case. If filled from above by mineral solutions which covered the globe, then he thought we ought to find beds of metallic matter in the valleys and plains also. Neither was he disposed to accept the views of the Plutonists, who regarded the veins as filled by "an injection from a fiery furnace below." Rather would he look upon them as contemporaneous both in formation and filling with the rocks in which they occur, being analogous to the granite veins of the same region. That the vein material did not adhere firmly to the wall rock, as is the case with the granite veins,

[a] This deceptive appearance, it may be stated, is due to the fact that the melaphyr at the time of its extrusion was in a highly liquid condition and flowing out over the uneven surface of the conglomerate filled in all the inequalities, so closely welding itself as to form what was apparently one and the same mass. When subsequent erosion cut away a considerable portion of both rocks the appearance of isolated patches of melaphyr here and there on the eroded surface of the conglomerate was quite misleading. Some more recent observers have since committed the same blunder of observation and faulty deduction with far less excuse.

was to him no argument against this view. "In one case the vein is lapideous, in the other it is metallic; they are different."

As has been already noted, Olmsted's work in North Carolina was continued after his resignation by Prof. Elisha Mitchell, who was transferred from the chair of mathematics to that of chemistry, mineralogy, and geology at the time of Olmsted's resignation.

Elisha Mitchell's Work, 1827–28.

Like Olmsted, Mitchell was born in Connecticut and graduated at Yale, going to North Carolina about the same time as did the former. He was known as a man of great culture and erudition, but had manifested no indications of a particular leaning toward geology until the transfer above noted, and to-day his fame probably rests more upon his knowledge of the physical geography and botany of North Carolina than of its geology. He was an enthusiastic explorer and collector, and, as is well known, finally lost his life on Black, now Mitchell, Mountain in 1857.

Fig. 18.—Elisha Mitchell.

His two most important papers on geology were published in 1828 and 1829, the first relating to the origin of the low country of North Carolina and the second to the geology of the gold regions. In 1842 he published a summary of his work in the form of a text-book for his classes, accompanied by a small geological map of the State, the only map of its kind thus far prepared. A report on the mineralogy of the State was also prepared by his assistant, C. E. Rothe, of Saxony, in 1827. A geological map of the eastern half of the State was said to have been made, but never published.

Mitchell, in his paper on the origin of the low country, took the ground that the various strata there found were formed in the bed of the sea and became dry land through the depression of the level of the ocean or the elevation of the land by a force operating from beneath. The shells found by him in these beds proved, in his judgment, that they were of comparatively recent origin, but just how recent he was not prepared to say. The presence of bones of elephants and mastodons, however, indicated to his mind an elevation prior to the Noachian deluge, to which catastrophe he evidently attributed their burial.

In 1829 Mitchell published in the American Journal of Science an article in which he threw doubt upon the statements and theories of Olmsted and Rothe regarding the origin and occurrence of gold in the State. It will be remembered that Olmsted considered the gold to be limited to the area occupied by the argillite, while Rothe considered granite as the base of the gold-bearing formations. Olmsted further argued that the gold occurred in the diluvial formation, while Rothe believed that the gold now found in the alluvial was derived from veins and spread over the country by a flood of waters breaking through the Blue Ridge and rushing in torrents over the entire gold-bearing region.[a]

Mitchell's Criticism of Olmsted and Rothe, 1829.

Mitchell's idea, which is undoubtedly the correct one, was that the gold occurred originally in veins and perhaps in part disseminated throughout the country rock, which was in itself in part primitive and in part secondary. From these rocks it was set free through atmospheric decomposition and subsequently distributed by gravity and running water.

Mitchell's paper is of further interest in that it contains a colored geological map of the gold region, the rocks being classified as primitive, transition or slate, old-red sandstone, and alluvium.

Although the day of the cosmogonist was fast drifting into the obscurity of the past, there were, nevertheless, occasional writers who still preferred to ignore facts of observation or the efficiency of simple causes and to seek for more difficult or more mystical methods of accounting for phenomena than those furnished by the observation of processes now in action. Thus Benjamin Tappan, in discussing the bowlders of primitive and transition rock found in Ohio (glacial erratics), objected to the commonly accepted idea that such were necessarily foreign to the locality, brought by currents of water or floating ice in immense inland lakes. He frankly acknowledged, however, his own inability to account for their presence, but ingenuously claimed that "ignorance is preferable to error," and added: "It may therefore be asked why may not these rocks have been created where they are now found?" Or, "Again, why may they not have been thrown out by earthquakes or volcanoes?"

Tappan's Ideas on the Drift, 1828.

Groping though this writer may have been, it is questionable if his ignorance were not preferable to the kind of knowledge manifested by a writer (signature "A") in the American Journal of Science of two years previous, who would account for the drift on the supposition that the earth's revolution, amounting to 1,500 feet a second, was suddenly checked. This, he thought, would result in the whole mass

[a] Rothe had previously (1826) expressed the idea that the gold was derived from the bursting asunder of the gold-bearing veins by subterranean explosions and the gold thus scattered over the adjacent regions, some of it being carried down in the water courses.

of the surface water rushing forward with inconceivable velocity, until overcome by opposing obstacles or exhausted by continual friction and the counterbalancing power of gravitation. The Pacific Ocean would thus rush over the Andes and the Alleghenies into the Atlantic, which would in the meantime be sweeping over Europe, Asia, and Africa. "A few hours would cover the entire surface of the earth, excepting, perhaps, the vicinity of the poles, with one rushing torrent, in which the fragments of disintegrated rock, earth, and sand would be carried along with the wreck of animal and vegetable life in one all but liquid mass."

The Dark Ages of Geology.

The period that may with propriety be called the dark age of geology was that prior to the discovery and general recognition of the value of fossils in stratigraphy—the fact that the relative age or stratigraphic sequence of sedimentary rocks could be determined by means of the plant and animal remains they may contain.

According to Dr. Archibald Geikie, in his Founders of Geology, credit must be given to the Abbé Giraud-Soulavie for having first planted the seeds of stratigraphic geology. In a paper read before the Royal Academy of Scientists in Paris in August, 1779, Soulavie described the calcareous mountains Vivarais as made up of limestones belonging to five different epochs, the strata in each being marked by its own peculiar assemblage of fossils.

These views, though undoubtedly correct in the main, were not generally accepted even in France, a fact thought by Doctor Geikie to be due mainly to the wretched style in which they were set forth, and the Abbé's fame has been eclipsed by more brilliant successors, among whom may be mentioned Desmarest, Rouelle, Lamanon, Cuvier, and Brongniart.

Cuvier, it will be recalled, was primarily a biologist, and may well be considered the first vertebrate paleontologist—the first to announce that the globe was once peopled by vertebrate animals of a type which have long since disappeared. In connection with Brongniart, Cuvier published in 1808 a memoir containing the results of their joint studies in the basin of the Seine. They showed that the formations there existing were arranged in a definite order and could be recognized by their lithological and paleontological characteristics. Although subsequent research has naturally tended to show that the observations and deductions of these early workers were not in all cases correct, it may, nevertheless, be said that they established on a basis of accurate observation the principles of paleontological stratigraphy, demonstrated the use of fossils for the determination of geological chronology, and paved the way for the enormous advances which have since been made.

When one recalls the avidity with which each new suggestion is seized upon by the scientists of to-day, it seems strange that so promising a field of investigation as was here thrown open should not have been immediately occupied. Nevertheless, it was not until 1828 that an American geologist took up the matter with an apparently full appreciation of its possibilities. In that year Dr. S. G. Morton, the paleontologist, read before the Philadelphia Academy of Sciences, from notes furnished him by Lardner Vanuxem, what was probably the most important paper of the year, relating to a possible subdivision of the heretofore so-called alluvial or Tertiary deposits of the Atlantic coast. The most important feature of this paper, as may be surmised, lay in its announced recognition of the value of fossils for purposes of correlation. With the exception of Prof. John Finch, already mentioned, writers up to this time had very generally referred to these deposits as belonging to a single formation, either alluvial or Tertiary, as the case might be. Vanuxem here asserted for the first time the existence of both Secondary and Tertiary formations, and showed "that the two formations may be at all times unequivocally identified by their fossil remains." The relative geological position of the beds he gave as below:

First Attempt at Correlation, 1828.

Modern alluvial	Vegetable mold	7
	River alluvium	6
Ancient alluvial	White siliceous sand	5
	Red earth	4
Tertiary	Beds of Ostreae Mass of limestone, buhrstone, sand, and clay	3
Secondary	Lignite	2
	Marl of New Jersey	1

In 1828 Dr. C. T. Jackson, of Boston, in company with Francis Alger, published in the American Journal of Science a series of papers bearing on the mineralogy and geology of a part of Nova Scotia. These, although mainly of a mineralogical nature, contained much material which at the time was valuable, and were accompanied by a colored geological maps This showed the distribution of the various geological formation. (identified mainly on lithological grounds) of the northern half of the peninsula. A broad belt of transition clay-slate was represented as extending from the Gut of Canso to St. Marys Bay. This was bordered on the northeast by a narrow bed of alluvium, the immediate border of the Bay of Fundy being occupied by trap rock or *greenstone*, as it was then called. A wide band of red and gray sandstone, alternating with shale and carrying beds of coal, occupied the region south of Minas Basin and all of the Cumberland County peninsula. This sandstone was described in considerable detail, and from its fossil contents was judged to be a secondary rock, although evidently older than

Jackson and Alger's Work in Nova Scotia, 1828.

SAMUEL GEORGE MORTON.
Physician and Paleontologist.

the trap—a recognition here of the value of fossils for stratigraphic purposes.

The clay-slate of the South Mountains he regarded as belonging to the transition class, since it dips 50° or 60° to the northwest, while the sandstone dips at an angle of only 10° or 15° to the north, clearly indicating the former rock to be of greater antiquity than the latter. Moreover the slate contained only marine fossils. It was regarded also as having existed before the neighboring plutonic rocks had emerged from the central region of the earth.

The granite was regarded as being undoubtedly of greater age than the clay-slate, since it contained "no relics of organized beings." He did not, however, consider it as belonging to the oldest primitive rocks, since it showed at places a brecciated structure, contained black mica, and was "lacking in the metalliferous compounds and minerals which characterize the ancient formations." "It probably belongs," he wrote, "to the third or newest formation of Werner."

Concerning the source of the trap and its relationship to the sandstone, he wrote:

The sharp fragments of the breccia and the breaking up of the strata also shew that the production of this rock or, rather, its nonconformable position on the sandstone strata, was effected suddenly. Whether it was ejected from the inaccessible depths of the Basin of Minas, or was thrown directly up through the strata of sandstone, we can not determine; but the occurrence of the trap only on the borders of the basin, which it almost surrounds, leads to the belief that this cavity was the crater, if it may be so called, from which, in former times, the trap rocks issued. The same remarks will apply to the whole North Mountain range, except that they probably originated from the unfathomable deeps of the Bay of Fundy, which is completely skirted on either side by trap rocks.

It will be noted here that Jackson for the first time cut loose from the Wernerian (Neptunian) doctrine. He realized this and stated that the evidence found convinced him of its insufficiency, and he was obliged to allow the superiority of the igneous theory as taught by Hutton, Playfair, and Daubeny.

Writing of the origin of the bed of hematite iron ore of the South Mountain region and its relation to the granites, he said:

Speculative geologists would doubtless regard the protrusion of the granite from the central regions of our globe as the cause of the disruption of the strata of clay-slate which was thus raised from the bottom of the sea, bearing with it the spoils of the ocean. The layers would thus be broken, their edges thrown up at an angle, and, by the contraction of the subordinate rocks, the superior strata being fixed, or the protrusion having carried the rocks so far as to poise the strata in a perpendicular position, a chasm would be formed into which the ore of iron was afterwards poured from above by a second submergence. From the similarity of fossils we should think the bed of iron ore must have been immediately formed after the disruption of the strata.

In 1833 a revised edition of the work was published in the Memoirs of the American Academy of Arts and Sciences. This was referred to by Featherstonhaugh in his journal, as "the neatest and best executed work on geology which has been gotten up in the United States."

Dr. Charles T. Jackson was born at Plymouth, Massachusetts, June 21, 1805; was graduated at the Harvard Medical School in 1829, and settled down to the practice of medicine in Boston in 1833, having spent a portion of the intervening years in Europe. He shortly, however, abandoned his medical practice in order that he might devote himself to chemical and geological investigations more to his taste. In 1836 he was appointed State geologist of Maine, and published during the three years he held that office three octavo reports comprising some 1,000 pages and an atlas of 24 plates. These volumes, while recording a large number of disconnected observations, contain nothing of striking interest or importance. They are devoted also largely to economic questions. It must be remembered, however, that the country at that time was largely a wilderness, without rail or carriage roads, and many of his journeys were made by canoes on streams and lakes.

Sketch of C. T. Jackson.

In 1839, as State geologist, he made a survey of Rhode Island, and in the year following submitted the manuscript copy for his report, 1,000 copies of which were issued, constituting the first, last, and only official account of the resources of the State ever published (Woodworth). In 1840 he began work upon the geology of New Hampshire, having been appointed geologist for that State September, 1839. This survey lasted until 1843, the final report appearing in 1844. It was while in the prosecution of this work that he made the discovery of tin ore at Jackson, and from it smelted the first bar of metallic tin produced in America.

In 1847 Jackson was appointed United States geologist to report on the public lands in the Lake Superior region, but spent only two seasons in the field, resigning for personal and political reasons in 1849. It was through his instrumentality, however, in part, that the copper regions of Lake Superior were opened up. Other economic work of Jackson which needs mention is that in connection with the discovery and description of the emery mines at Chester, Massachusetts.

After withdrawing from the Lake Superior survey, Jackson devoted himself largely to laboratory work, having an office at 32 Somerset street, Boston. As is well known, he was one of the claimants for priority in the discovery of the anæsthetic properties of ether. He was well and favorably known as a chemist and all-round naturalist, and is described as "an enthusiastic personage, a ready conversationalist, even eloquent in his speech and fond of story telling—a man of large stature, square shoulders, and massive head." As a geologist he was conservative almost to the point of obstinacy, as is shown by his steady adherence to the older forms of classification, though finding it necessary to depart somewhat from the ideas of Werner. He

CHARLES THOMAS JACKSON.

State Geologist of Maine, New Hampshire, and Rhode Island.

was but little given to theorizing, at least so far as is shown by his published works, and announced few, if any, new principles. His fame rests rather upon the extension of the geographic boundaries of our knowledge and the development of economic resources.

The matter of the relative age of rocks as indicated by their position with respect to horizontality, which had been discussed by Cleaveland in 1816, Maclure in 1825, and Jackson in 1828, was again taken up by Vanuxem in 1829. In a paper in the American Journal of Science in this year he called attention to several errors promulgated by the American geologists, the first of which related to the existence of Alluvium and Tertiary rocks in the Southern Atlantic States, as he had previously announced in conjunction with Morton.

Vanuxem's Views, 1829.

Of almost equal importance was the objection raised at this time to the prevailing assumption that all of the so-called secondary rocks were horizontal in position, or, on the other hand, that all horizontal rocks were, therefore, secondary. He pointed out that rocks composed of mechanical particles when undisturbed would form horizontally lying masses, but that both uplifting and downfalling forces had existed and there was no certainty that such had acted in a uniform manner, giving rocks of the same age the same inclination. Therefore the position of beds as regards horizontality, he argued, could not be relied upon to indicate age. "The analogy or identity of rocks," he wrote, "I determine by their fossils in the first instance and their position and mineralogical characters in the second or last instance." This is perhaps one of the most important generalizations that had thus far been made by any American geologist.

Vanuxem was a Philadelphian by birth, but received his mineralogical and geological training at the School of Mines in Paris at the time when Brongniart and Hauy were both active. Graduating in 1819, he returned to America and assumed the chair of chemistry in Columbia College, South Carolina, resigning in 1826 to undertake some private mining work in Mexico. In 1830 he removed to a farm near Bristol, Pennsylvania, which continued to be his home during the rest of his life, though connected with the New York State survey during 1837-43.

Sketch of Vanuxem.

He is represented as a man of slight build, active and energetic, and with great powers of endurance; one who loved his work for the work's sake, and was always averse to receiving pay for his services excepting when circumstances rendered it absolutely necessary.

According to his biographer, he had the reputation of being visionary and full of untenable theories. Be this as it may, his published writings show no such failing, and there are few men of his day who saw more clearly or reasoned more correctly. His published writings were, for that time, remarkably free from error. As a geologist he ranks with those who have put forward new ideas rather than those who have extended geographic boundaries.[a]

In 1829 there appeared the first American, from the third English, edition of Bakewell's Introduction to Geology. This was edited by Silliman, and was accompanied by the latter's Outline of the Course of Geological Lectures given in Yale College. The reason for the reprint, as given by Professor Silliman in the preface, was that he might place in the hands of his classes a comprehensive treatise on geology which they "would be willing to read and able to understand." The lecture notes, which merit our attention here, comprised 126 pages and may be reviewed in some detail as illustrating the character of instruction given at that time.

First American Edition of Bakewell's Geology, 1829.

Silliman announced himself as being neither a Wernerian nor Huttonian, but simply a student of facts. The classification was, however, largely Wernerian, though he says: "It is one of convenience merely, and therefore there is no hesitation in deviating from it, or in substituting other views, when they appear preferable." The discoveries of geology he regarded as consistent with the biblical account, and "respecting the deluge, there can be but one opinion * * * geology fully confirms the scripture history of that event."

The earth, he conceived, as at an early stage covered superficially by a watery abyss, containing in solution acids and alkalies such as would augment its solvent powers. He regarded the solubility of all the existing elements forming the crust of the globe as clearly and actually demonstrated, but found a serious difficulty in attributing to the quantity of waters that now exist * * * sufficient power to suspend all the materials of those rocks that bear marks of deposition from a state of chemical solution. Among other possibilities he, however, seriously considered that of a portion of the then existing waters having "been received into cavities of the earth, to await a future call to deluge the surface anew." From this solution the primitive rocks—granite, gneiss, mica, slate, and some of the limestones—were regarded as having been deposited, the author thus far following Werner.

The question as to the origin of mountains and of the continents was, with him, a vexed one. "Some imagine that entire mountain ranges and even entire continents have been raised by the force of subterranean fire," and he saw no inconsistency in admitting that both igneous and aqueous agencies might have been active in their production. But, as to the source of the materials from which they were formed, he felt by no means clear. If supplied from regions imme-

[a] According to Hall (Transactions of the American Association of Geologists, 1840–42), Vanuxem was the first to point out the similarity of some of the western formations with those of New York, identifying the lower rocks of Ohio, Kentucky, and Tennessee with the Trenton limestone.

LARDNER VANUXEM.

Geologist of New York State Survey.

diately beneath, what fills the void? he asked. If it is arched over from side to side, what security is there that subterranean fires will not melt down the abutments and undermine the continent? But, whether the mountains were raised from below, left prominent by the subsidence of the contiguous regions, or were reared by accumulation, he regarded as immaterial for his present purpose. "It is agreed on all hands that they existed before the subsidence of the early ocean, whose retreat must of course have first exposed their summits."

Among the rocks belonging to the transition period he included the crystalline limestones—marbles—of Bennington, Middlebury, and Swanton in Vermont; the graywackes of the Chaudiere Falls in Lower Canada, of Rhode Island, and of the Catskill Mountains; the breccia marble of Point of Rocks, Maryland; and the conglomerates of Dorchester and other locatities in Massachusetts. These, as is well known, are now relegated to various widely separated horizons, extending from the Cambrian in the case of the Swanton marbles to the Triassic in the case of that of Point of Rocks.

The manner in which the fossil organisms were conceived to have become imbedded in their various matrices is interesting:

> We can not doubt that the animals received their existence and lived and died in an ocean full of carbonate of lime, in solution, or in mechanical suspension, or both. When they died they of course subsided to the bottom and were surrounded, as they lay, by the concreting calcareous matter; * * * the interstices were filled by the calcareous deposit, and this being more or less chemically dissolved, produced a firm, subcrystalline mass, a section of which shows the animals sawn through.

Concerning the value of such remains, he was fully cognizant: "Fossil organic bodies contained in rocks are now considered as good indicia of the geological age and character of the strata in which they occur."

As with others of his time, Silliman was a believer in the Noachian deluge. Indeed, in point of detail, he outdid all others in his attempts at harmonizing apparently conflicting statements and ideas and wrote, as Huxley has aptly expressed it, "with one eye on fact and the other on Genesis." "There is decisive evidence that not further back than a few thousand years an universal deluge swept the surface of the globe." This deluge, it should be remarked, was considered quite distinct from the original, primeval ocean, and to have been brought about through direct intervention of the Creator for the purpose of punishing and partially exterminating the race. It was sudden in its occurrence, short in duration, and violent in its effects. In order to account for the biblical expression, "the fountains of the great deep were broken up," Silliman offered the suggestion that, contemporaneous with the forty days and nights of rain, a deluge of water burst forth from the bowels of the earth, whence it was forced by the sudden disengagement of gases, the presence of the subterranean water he having already conveniently accounted for by assuming that it was derived from the primeval ocean at the time it shrank away and left the dry land. Sufficient water to cover, when forced to the surface, the highest mountains, could, he calculated, be contained in a cavity the cubical content of which was only one two hundred and sixty-fifth part of the globe.

Assuming that the antediluvian mountains were the same as to-day, but somewhat higher (say, 5½ miles), and accepting the fact that they were covered by the water, Silliman proceeded to show that, with a time limit of forty days, the water rose at the rate of a foot in two minutes—i. e., 30 feet an hour, or 181 feet in the time of a common flood or ebb tide, 362 feet in the time of the ordinary ebb and flow of the tide, or 726 feet in twenty-four hours.

The inequalities in the surface of the land would, however, increase even this rate, and a very graphic picture is drawn of "the inconceivably violent torrents and cataracts everywhere descending the hills and mountains and meeting a tide rising at the rate of more than 700 feet in twenty-four hours."

It is to such a catastrophe that he believed to be due the extinction of whole races of vertebrate animals, like the Siberian mammoth and others. That such would be amply sufficient no one will be likely to doubt.

CHAPTER III.

THE ERA OF STATE SURVEYS, FIRST DECADE, 1830–1839.

The decade beginning with 1830 stands out prominently as an era of public surveys. With the exception of the single abortive attempt made in North Carolina in 1824 no surveys at other than private expense had thus far been attempted, though the subject had more than once been agitated. During this interval, however, scarcely a year passed but witnessed the establishment of a State survey or the organization of an exploring expedition, to which a geologist was attached. Thus were established surveys in Massachusetts in 1830; in Tennessee in 1831; Maryland in 1834; New Jersey, Connecticut, and Virginia in 1835; Maine, New York, Ohio, and Pennsylvania in 1836; Delaware, Indiana, and Michigan in 1837, and in New Hampshire and Rhode Island in 1839. In addition, the United States Government for the first time recognized the practical utility of the geologist by authorizing the surveys by G. W. Featherstonhaugh of the elevated country between the Missouri and Red rivers in 1834 and of the Coteau des Prairies in 1835, and by D. D. Owen of the mineral lands of Iowa, Wisconsin, and Illinois in 1839.

The Wilkes exploring expedition, with J. D. Dana as geologist, was also organized and sent on its way in 1838. Beyond the limits of the United States Abraham Gesner was doing important work as provincial geologist in Nova Scotia and New Brunswick. Eaton and Maclure were still in the field, but new workers were rapidly forcing their way to the front, and the influence of the two pioneers was already on the wane. Other names which appear in this decade and grow to prominence are Timothy A. Conrad, James Hall, William Mather, D. D. Owen, J. G. Percival, and H. D. Rogers.

Eaton's Geological Text-book, 1830-1832.

In 1830 Eaton published the first edition of his Geological Text-book, an octavo volume of 64 pages, accompanied by a colored geological map exhibiting a general view of the economic geology of New York and part of the adjoining States, the work for which had been done under the direction of the Hon. Stephen Van Rensselaer.

The book is worthy of a somewhat extended notice, since it gives us an insight into the character of the instruction furnished students at that time at the Rensselaer Institute, and also, since it was Eaton's second attempt at preparing a text-book. His first attempt, it will be remembered, was his Index to the Geology of the Northern States, published in 1818, a second edition of which appeared in 1820. In these works he was anticipated only by Parker Cleaveland's Text-book of Geology and Mineralogy, which appeared in 1816, though the volume we are now discussing was anticipated in 1826 by the work of Emmons.

Eaton's general views regarding the formation of the various geological deposits are summed up as follows: "The earth is composed of masses of rocks and detritus which are more or less extensive and uniform in their characteristic constituents." "These masses are mostly in regular deposits, and those of the same structure and composition regard the same order of superposition in relation to each other." A few of the outermost masses, having no reference to each other, he called "anomalous deposits." He divided these regular deposits into five series, called classes, each of which "consists of three formations which are found to be corresponding equivalents in all the series. The lowest formation in each series is *slaty* or *argillaceous* and always contains beds of *carbon* in the state of coal, anthracite, or plumbago." The next is silicious and destitute of beds of carbon, and the uppermost, also lacking in carbon, is composed chiefly of carbonate of lime.

All the primitive formations he regarded as deposited in the form of concentric spheres like the coats of an onion. These contained the materials of which all outer formations were afterwards made up. "Soon after these deposits were laid down they were broken up through several northerly and southerly rents by a very great force exerted immediately beneath the lowest of the primitive strata. In this semi-indurated and broken state materials were readily furnished for the outer strata." The source of the force producing these rents, it will be remembered, was in his early works regarded as problematical (p. 238).

In this last work he, however, solved the problem in a manner best understood by reference to the figures here reproduced, which he claimed were an improvement on those given in the Index.

The earth is here supposed to be cut into two parts at the forty-second degree of north latitude. Large bodies of combustibles of an undetermined nature, it will be observed, are conveniently stored under what are now the regions of maximum disturbance, as the Rocky Mountains, New England, Great Britain, the Alps, Pyrenees, Caucasus, and the Himalayas.

In the second figure combustion is supposed to have taken place, whereby an explosion was produced which burst through the primitive and transition series, and appalling indeed must have been the results.

A geological segment, not reproduced here, gives in greater detail a section across the American continent, showing the internal nucleus, the areas of combustible matter under New York State and the Rocky Mountains, and the alternation of the regular deposits, illustrating his ideas as to the present condition of the earth. The combustible

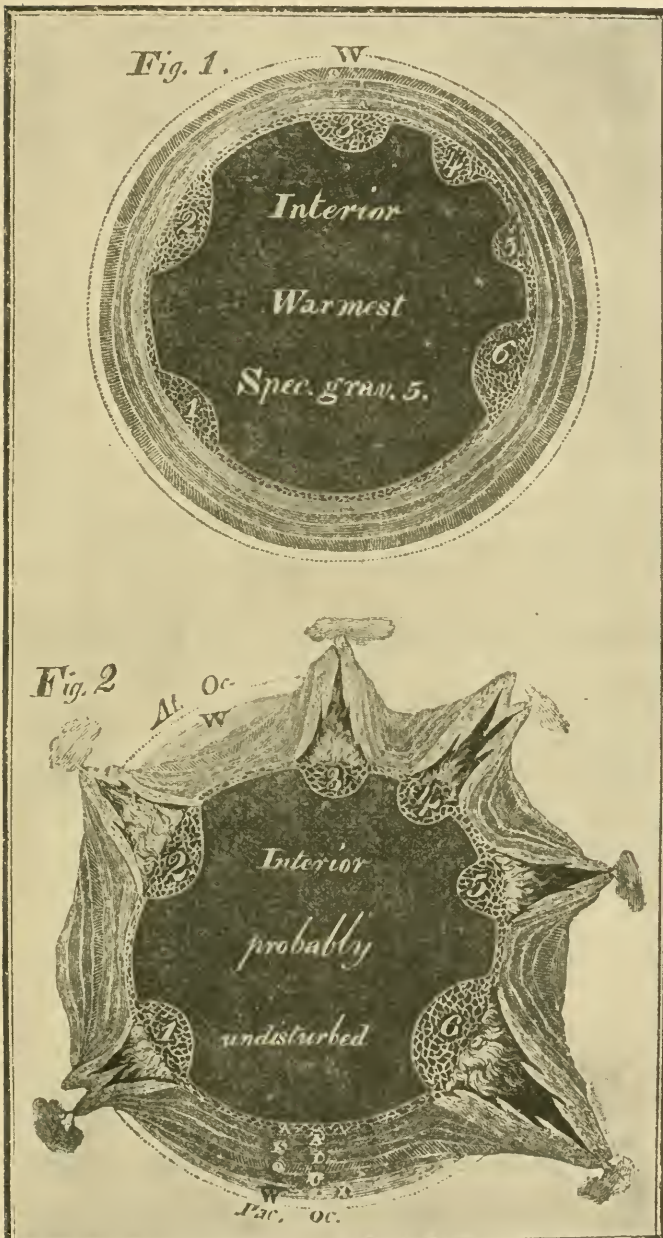


Fig. 19.—Eaton's Transverse Sections of the Globe.

materials at this time are supposed to be nearly exhausted, although still sufficient to cause ordinary earthquakes.

The superficial rocks of the crust, as shown in this section, were divided into four series, each of which was made up, in ascending order, of Carboniferous, Quartzose and Calcareous rocks. The definitions of the various classes forming the transition and secondary remained much as in the early work, excepting that he divided his Class III into a lower and upper division and added a fifth series, the Tertiary, this latter including those strata which contained remains of viviparous vertebral animals.

The so-called anomalous deposits were those which have been produced at the earth's surface by fusion or disintegration of regular strata, and were divided into (1) Volcanic deposits, (2) Diluvion, (3) Postdiluvion, and (4) Analluvion, the last including what are known as residual deposits—that is, those which result from decay in situ.

In the second edition of this work, published in 1832, the same general ideas were advanced regarding the formation and uplifting of the various rocks; a much more satisfactory chapter added on the character and objects of geology, and also a chapter on organized remains as auxiliaries in the determination of rocky strata, in this respect the second edition being decidedly in advance of the first.[a]

Many of the ideas put forward in the chapter on the character and objects of geology are, in the light of to-day, peculiarly interesting. The desire to harmonize all phenomena witnessed with the biblical account of the deluge was still manifested:

> Geological facts lead us to the history of created beings long anterior to written records. Such records may be erroneous, and we have no means of correcting them. But geological records are perpetual, unvarying, and can not be vitiated by interpolations or counterfeits. For example: The written history of the deluge might be varied more or less by erroneous copies and incorrect translations. But the geological records of divine wrath poured out upon the rebellious inhabitants of the earth at that awful period can never be effaced or changed. These later records add, to the Mosaic account, that even the antediluvial beasts of the forests and fens partook of the ferocious nature and giant strength of antediluvial man.

The bed of Lake Ontario Eaton regarded as made by the rapid disintegration of Saliferous and Carboniferous rock, while the beds of Lake Champlain and the Mohawk and Hudson rivers were thought to have originated, for the most part, by the disintegration of rocks at

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[a] The edition of 1832 was issued and sold under direct supervision of the author. The following note relative thereto is in possession of the present writer:

To General Howe (or whoever has received my geological text-book), deliver a copy of my text-book to Professor Silliman and another to Professor Tulley (?), on my account. Charge them to William S. Parker and I will cause the same to be charged to me and also to be credited to you. July 24, 1832.

AMOS EATON.

N. B. I publish this edition myself, and have paid all cash, by way of trial.

line of contact between different formations. "The deep bed of the Hudson across the Highlands, however, may, without extravagance, be ascribed to the fusion by volcanic heat which produced the basaltic Palisades below the chasm. The same hypothesis may be well applied to the channel of the Connecticut River north of the northern line of Massachusetts, whence the volcanic lava flowed which now covers a series of basaltic prominences which form the northern part of Long Island Sound." And this as late as 1830–1832! Yet the Rensselaer school, where Eaton was teaching, was, and continued to be for many years, the chief training school for American geologists. Fortunately, his students were taught to *think* and not to blindly follow.

Eaton claimed at this date (1832) to have devoted more time and labor to American geology than any other individual, and credits Gen. Stephen Van Rensselaer with having furnished the necessary facilities. "I made the first attempt," he wrote, "at a systematic arrangement of American rock strata." The various discoveries which he thought might be claimed as having been made under the auspices above noted are as follows:

(1) That each of the classes of rocks always begins with a Carboniferous slate and terminates with calcareous rocks, having a middle formation of quartzose.

(2) The discovery of ferriferous stratum containing argillaceous iron ores, and which extends unbroken from near Utica to the extreme termination of Lake Ontario, in Upper Canada.

(3) That the bog-ore properly belongs to the Tertiary formation.

(4) That talcose slate is the grand repository of hematitic iron ore, peroxide of manganese, and native gold.

(5) That the Corniferous lime rock is the true carboniferous only.

(6) That crystalline granite is not entitled to a place among general strata, as it is never found other than as a bed or vein.

(7) That granular quartz rock and granular lime rock are entitled to a place among general strata.

(8) That all primitive rocks, excepting granular quartz and lime rocks, are contemporaneous.

(9) That there is evidence of a diluvian stratum having been deposited near the termination of the deluge, which formed an universal mantle about the earth.

In discussing the "regular" deposits, he wrote:

They exhibit grounds for conjecture, if not absolute demonstration, that the surface of the earth had undergone five general modifications which no animals survived. Four of these modifications were followed by as many new creations of animals, two new creations succeeding the final depositions of all regular strata. In the whole there appeared to have been five creations of animals at least, and perhaps ten, since the primitive mass of earth was formed.

In his chapter on soils, it is instructive to note, he recognized and emphasized a principle now generally accepted, to the effect that the fertility of the soils does not depend upon ultimate chemical constitution, but rather upon physical properties; that a fertile soil should contain, first, sufficient stones and pebbles to keep it open and loose; second, sufficient clay to absorb and hold water in the right proportion; and third, sufficient fine sand to prevent the clay from baking in time of drought.

That the fertility of a soil could not be told by a chemical analysis had been stated by him some years earlier, as follows:

Suppose, in one specimen, the soil, etc., should be quartz, in another feldspar, in another hornblende, in another sapphire, in another diamond, would there be any difference in the influence of the sand, etc., upon the productive quality of the soil on account of the different ultimate elements of which these different minerals are composed? Should they be so far decomposed, at some future period, as to become an impalpable powder, perhaps they may then differ in their influence upon vegetation. Perhaps we may foretell the future state of the country a century or two to come, where such extreme disintegration is effected. But the difference in the ultimate constituents can not possibly affect the question of fertility or barrenness *at the time the analysis is made.* For whatever effect can be ascribable to the one is equally a property of the other. They all hold water on their surfaces by the attraction of adhesion; they all keep the soil duly open and porous to give passage to the roots of vegetables; they all aid alike in bracing up plants and in keeping them in a fixed position, etc. Whatever is effected by one is effected by all—size, form, quantity, and all circumstances, other than their constituent elements, agreeing.[a]

To this second edition he added a chapter of some 11 pages on the science of mining, one of 12 pages on localities, and 5 pages on fossils. His gradually expanding views as to the value of fossils in geological work are shown in his paper on Geological Equivalents of this year (1832). He here advanced the idea that the enumeration of the mineral constituents of rocks could never be satisfactorily applied for the determination of the relative position of strata, but that recourse must be had to the organic remains. "We find the same organized remains associated with equivalent strata in every part of the earth."[b]

If we are to judge from the preface of the edition of 1830, Eaton was by no means lacking in egotism, and had, at times, an unfortunate way of expressing his opinions, such as must have aroused antagonism

[a] American Journal of Science, XII, June, 1827, p. 370.

[b] The first edition of Eaton's work was somewhat savagely reviewed by a writer in the North American Review for April, 1831. From its perusal one might be led to suppose that the following extract from a letter by Eaton to Silliman in 1839 had a sounder basis than Eaton would himself be likely to acknowledge. He wrote: "I was one of your earliest correspondents on geology, consequently it is to be presumed that I have introduced more errors to the public through your journal than any other individual." Most writers will say things of themselves which they would resent if said by others.

in the minds of his collaborators. Thus, in referring to the work just mentioned, he wrote:

A *text-book* is too small a name for these days of puffing arrogance. But I propose to present all my *supposed heresies* to the geological fraternity in this form and under this title. And I beg the favor of the most rigorous criticism upon this book, small as it is. To stimulate men of science to the work of examination and of criticism, I will state that I intend to publish considerable in scientific journals, also a full system upon this plan. As I have had more than 7,000 pupils already (rather auditors), and shall probably have more still, it will be well for them "to be on the alert" if I am propagating errors. I am not in sport; I have, during the last fifteen years, traveled over 17,000 miles for the express purpose of collecting geological materials, the results of which are comprised in this little octavo pamphlet and exhibited in the accompanying map and wood cuts.

I may be accused of fickleness, on account of the changes which appear in every successive book I publish. I confess this is the ninth time I have published a geological nomenclature, and that I made changes in each of more or less importance. But I have always consulted my scientific friends, and every change was founded on new discoveries in "matters of fact."

And further on:

Students for whom this text-book is intended may feel no interest in anything *personal* relating to myself. But I will throw this paragraph in their way. I have been accused of arrogance for stating facts relating to American geology without formally bowing to European authorities. * * * I confess that this is a kind of "ipse dixit" text-book. It is so, because the plan does not admit of demonstration. In a future publication I intend to cite authorities from nature to illustrate my views. But I am prepared to abandon any of them, as I have frequently done heretofore, in cases of numerous errors, to which I am still subject.

Geology is a progressive science, and he who has any respect for his future reputation should be exceedingly cautious about committing himself on matters of fact or speculation. I confess that I have *most egregiously* violated this rule, but there are peculiar circumstances in my case, arising from my being "a hireling drudge" to the most munificent patron of this science (Stephen Van Rensselaer), which will palliate, at least, if not justify.

I despise arrogance; but I am within sixteen years of the "three score and ten," when the mind of man is averaged beyond the period of vigorous effort. About two score of these years have been devoted to natural science. I offer this as an apology for some dogmas forbidden to youth.[a]

Monthly American Journal of Geology, 1831.

In July of 1831 there appeared the first number of G. W. Featherstonhaugh's Monthly American Journal of Geology and Natural History. This proved a short-lived but vigorously conducted journal in which essays on geology, as understood by the editor, occupied a leading part in each number. Troubles, financial and otherwise, beset the venture, and amongst the "otherwise" may be mentioned a lack of appreciation and support where he apparently had a right to expect both. "So that a work which has hitherto been stamped with general approbation. * * *

[a] One can almost imagine him saying with Emerson "What is well done I feel as if I did, what is ill done I reck not of."

has not been permitted to have a single subscriber in New Haven, the pretended seat of an American Geological Society," is his fierce plaint in the ninth issue.[a]

Featherstonhaugh was a man of English birth and some means, who came to America when quite young apparently merely through love of

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[a] Featherstonhaugh's efforts seem to have been better appreciated abroad than at home, if we may judge from the following:

The editor lays before his readers, with a just pride and entire satisfaction, the following communication from the president of the Geological Society of London, and other distinguished naturalists:

LONDON, *June 18, 1831.*

MY DEAR SIR: We, your undersigned friends in England, are happy to learn that you propose to establish a new periodical work in the United States, which, in embracing all subjects connected with the natural history of America, is to be specially devoted to the accumulation of geological facts and phenomena.

Knowing your zeal and ability, we have great hopes that a work so directed will meet with every encouragement in your country, and we are certain that it can not but be of service to the cause of science in general.

We shall at all times be desirous of aiding you with any communication in our power, and we subscribe ourselves,

Yours, very faithfully,

RODERICK IMPEY MURCHISON,
President of the Geological Society of London.

DAVIES GILBERT,
Vice-President Royal Society.

W. D. CONYBEARE, F. R. S., F. G. S., etc.

A. SEDGWICK, F. R. S., F. G. S., etc.,
Fellow of Trinity College, Cambridge.

WM. BUCKLAND, D. D., F. R. S., etc.,
Christ Church College, Oxford.

GEORGE BELLAS GREENOUGH, F. R. S., etc.
CHARLES STOKES, F. R. S., etc.

P. S.—I can not refrain, in particular, on my own part, from expressing the desire which I feel for the appearance of the proposed publication, as likely to conduce in the most important points to the effective progress of geology; to ascertain in detail the suite of formations, and the series of organic remains distinguishing them in a new continent, so widely separated from the old, and embracing such a range of various climate. So to compare the phenomena with those of Europe has ever appeared to me the most material desideratum in geology, for we may be sure that any analogies which are common to localities geographically so distant, and placed under physical conditions so distinct, are, in truth, analogies belonging generally to the whole globe; and thus we shall obtain data adequate for the foundation of a general geological theory.

Well acquainted with the attention you have paid to the formations on this side of the Atlantic, I am convinced that the execution of this task can not fall into more competent hands.

W. D. CONYBEARE.

G. W. FEATHERSTONHAUGH, Esq., *Philadelphia.*

travel. Being of good presence—standing more than 6 feet in height, well educated, and an accomplished musician—he easily procured admission into the best of society, married an American girl, and established himself at Duanesburg, in New York, but was, apparently, never naturalized. He appears to have taken an active interest in agricultural, scientific, and political affairs, and, in company with Stephen Van Rensselaer, became one of the directors of the railroad from Albany to Schenectady, a charter for which was granted in 1826. The death of his wife and two daughters, however, caused him to leave Duanesburg and turn his thoughts toward exploration and science. He therefore removed to Philadelphia, where he established, in 1831, the journal above mentioned.

Sketch of Featherstonhaugh.

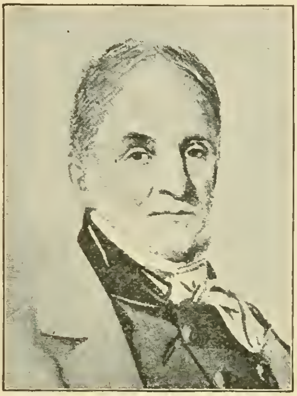

Fig. 20.—George William Featherstonhaugh.

In 1834, and again in 1835, he was appointed a Government geologist, but his work was extremely superficial and of only historical interest. Concerning his work in the elevated country lying between the Missouri and Red rivers—the Ozark region—and his subsequent work in the upper Mississippi region, Whitney, after numerous quotations, remarks:[a]

> From the above it will be seen that this so-called geological reconnaissance was about as worthless rubbish as could well be put together, neither correctly describing any facts which came under their author's observation, nor giving any theoretical views worthy a moment's notice, except from their absurdity.

The year 1831 seems, on the whole, to have been singularly uneventful in geological history, but few papers of importance appearing, although undoubtedly a large amount of hard, preliminary work was being done.

Geological Survey of Tennessee, 1831–35.

Perhaps the most important event of the year was the establishment of the State geological survey of Tennessee, with Gerard Troost, then professor of geology and chemistry in the University of Nashville, but formerly of Philadelphia, at its head. This survey continued in existence until 1845, during which time eight annual reports were made, the first two of which were not published. The third report, made in October, 1835, comprised but 32 octavo pages and dealt particularly with the extent of the coal formations and investigations of the soil, marls, and iron ores. It was accompanied by a geological map, in which the coal area, colored in pink, was indicated as extending in a gradually narrowing belt from the northeast to the southwest in the region lying west of the Tennessee River.

[a] Upper Mississippi Lead Region, 1862, p. 80.

Troost's fourth report appeared in 1837, in form of a pamphlet of 37 pages. Of these the first 20 were given up to a general exposition of geology, as he understood it. This was followed by a description of that part of the State lying south of the Hiwassee River and east of the Tennessee, and known as the Ocoee district. A map of this district and a colored geological section were given, the latter extending in a general northeast to southwest direction from the Tennessee River to a point near Nicajack. The entire area to the point of the intersection of the Chattanooga Creek was colored as occupied by "grauwacke," with outcrops of primordial limestone coming to the surface near Coqua Creek. The region to the west of Chattanooga Creek was represented as underlaid by mountain limestone, with the Coal Measures forming Lookout Mountain and Raccoon Mountain. These Carboniferous rocks, it should be noted, were indicated as unconformable with all other rocks of the region.

Troost's Fourth Report, 1837.

The fifth annual report was made November, 1839, and comprised all told 75 pages, including an appendix. This was accompanied by a colored geological map of the State, the first which had thus far appeared, and also a colored section across the entire State from Roane Mountain, in Carter County, to Randolph, on the Mississippi. On this map the Roane Mountain rock was colored as primordial, mostly granite. An area from and including the Smoky Mountains to a point a little west of Kingston, on the Clinch River, was colored as transition, composed of graywacke, slate, limestone, and sandstone, all alternating with each other, and in strata highly inclined and dipping toward the southeast. From the last-named point to the Tennessee River the country was stated to be underlaid by mountain limestone horizontally stratified, upon which rested the Cumberland Mountains, composed of Coal-Measure rocks, mostly horizontally stratified, and the Buffalo and Harpeth hills, just east of the Tennessee River, which were put down as formed of siliceous strata, assuming sometimes an earthy appearance, sometimes that of chert, and horizontally stratified.

Troost's Fifth Annual Report.

The region west of the Tennessee was given as mostly occupied by secondary strata composed of Cretaceous marl, greensand, and clay, horizontally stratified.

It should be noted that Troost, while seemingly recognizing the importance of the fossils carried by the rocks of various ages, did not attempt to utiiize them systematically as means of correlation. On page 18, however, he wrote:

> The lowest part of the stratum, where it is near the encrinital limestone, often contains members of Encrinites, and other fossils of that stratum, and are invariably of a calcareous nature. This shows that the formation of those siliceous strata is more or less contemporaneous with the encrinital strata.

The condition of paleontological science at this date (1832), so far as it related to the Trilobites at least, is shown by Dr. Jacob Green's Monograph of the Trilobites of North America, a duodecimo volume of 93 pages and one plate of ten figures. Thirty-three species were described. In a supplement bearing date of 1835 this number was increased to forty. A series of casts, examples of which are still to be found in many of our educational institutions, accompanied the original publication.

Green's Monograph, 1832.

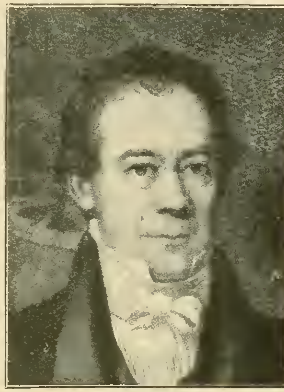

FIG. 21.—Jacob Green.

The true nature of the *Trilobite* was at that time not well understood. Green himself seems at first inclined to agree with Latreille, who, owing to their supposed footless condition, placed them intermediate between the Chitons and the Articulates.[a] Brongniart, Dekay, and others, it will be remembered, considered them as belonging to the *Entomostraca.*

A contemplated chapter on this branch of the subject remained unwritten, since the author felt that all matters of dispute were "put to rest by the late discovery of some living trilobites in the southern seas." Concerning the exact position in the zoological scale of these "living" forms there still exists some doubt. Dr. James Eights, who originally described them under the name of *Sperroma bumastiformis*, seems to have regarded them as Isopods. Emmons, in his Geology of the Second District of New York, on the other hand, referred to them as Trilobites, while Zittel, in the latest edition of his Handbook on Paleontology, refers them once more to the Isopods.

Green's ideas as to the value of fossils as indices of geological age were not as advanced as those of most of his colleagues or as his time would lead one to expect. After quoting some of the prevalent opinions, he adds in a footnote:

> Nothing can be more opposed to true science than to pronounce on priority of formation or the comparative age of rocks from either their structure or the organic remains they present.

Concerning Brongniart's expressed opinion relative to the preponderating value of fossil over lithological criteria, he wrote:

> This seems to us to imply an admission that nothing definite can be inferred from the *nature of the rocks;* moreover, that between the nature of the rock and the organic remains there may be a palpable discrepancy. * * * The event has proved, from what we have already mentioned, that no evidence as to priority can be obtained from the nature of the fossil remains displayed in particular strata.

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[a] The *Trilobites* have since been shown to have feet.

And this from a paleontologist!

Although the geological map referred to on page 219 was the most important of Maclure's works and the one upon which his fame as a geologist largely rests, there are at least two papers of later date that are worthy of consideration. The first of these bears the title Observations on the Geology of the West India Islands from Barbados to Santa Cruz, Inclusive. This was printed for the author in pamphlet form in 1832, while he was at New Harmony, Indiana. The mineralogical nature of the materials composing the islands was noted as well as many of the structural features. He thought to divide the islands into two distinct classes on geological grounds, the first, or most eastern, comprising the islands of Barbados, Marie Galante, Grande Terre in Guadèloupe, Desirade, Antigua, St. Bartholomew, St. Martin, Anguilla, and Santa Cruz. These he found composed mainly of shell-limestone or madrepore rock belonging to the transition class, though sometimes capped by secondary rocks. The second class, including the Grenadines, St. Vincent, St. Lucien, Martinique, Dominica, Basse Terre in Guadeloupe, Montserrat, Nevis, St. Christopher, St. Eustatia, and Saba, were more or less volcanic and regarded as probably thrown up from the bed of the ocean. Such an origin he felt to be proven by their containing intermingled masses of volcanic rock and coral or madrepore limestone. The idea that volcanic activity was dependent upon combustion, as the word is commonly used, still prevailed with him, and from the fact that the line of islands corresponded closely with the strike of the rocks composing them he thought that the seat of combustion probably existed in some stratified substance running parallel to the general stratification of the surrounding rocks. Further, since he found on the islands soufrieres which deposited sulphur as well as formed alum rock, he concluded that sulphur was one of the combustible ingredients.

Maclure's Geology of the West Indies, 1832.

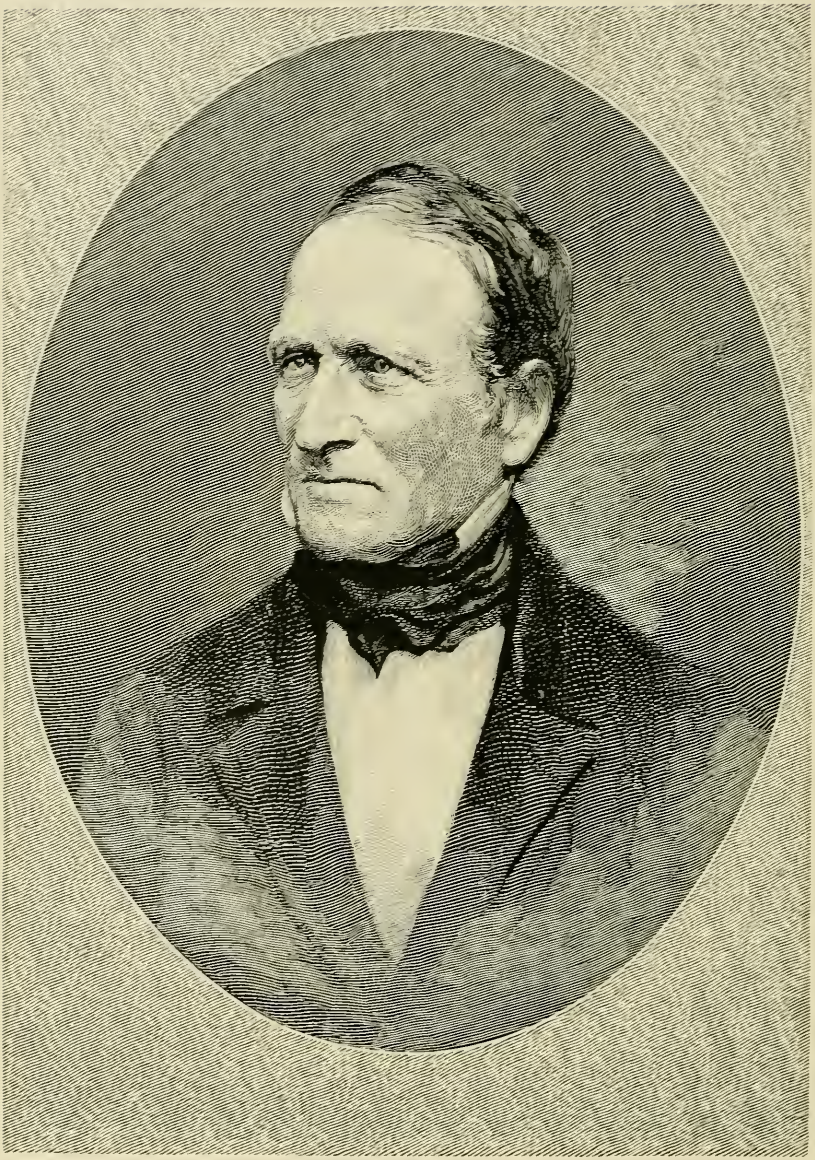
Maclure's second paper referred to, An Essay on the Formation of Rocks, or an Inquiry into the probable Origin of their Present Form and Structure, appeared in 1838. In this the rocks were divided into three classes: First. The Neptunian, including those plainly of aqueous origin. Second, the volcanic; and third, those of doubtful origin, under which head he would place gneiss, mica, and clay slate, primitive limestone, syenite, granite, greenstone, etc.

Maclure on the Formation of Rocks, 1838.

In 1832 the melancholy Conrad began the publication of his work on the fossil shells of the Tertiary formations of North America. This marks, according to Dr. G. D. Harris, "the beginning of systematic research into this part of our continent's history."

Conrad's Tertiary of North America, 1832.

The work was published in parts and in small editions, largely at Conrad's own expense, the numerous plates of illustrations being pre-



EDWARD HITCHCOCK.

Professor of Geology, Amherst College.

pared, even to the drawing on stone, by himself. Nos. 1 and 2 appeared in 1832, and Nos. 3 and 4 in 1833. These editions early became exhausted, and in 1893 a new edition was prepared through the instrumentality of Doctor Harris. It will be well to mention here that a second edition of his Medial Tertiary fossils was brought out this same year by Dr. W. H. Dall, working in conjunction with the Wagner Free Institute of Philadelphia.

The work of 1832–33 contained little of a strictly geological nature, being mainly devoted to a description of the various fossil invertebrates belonging to the Tertiary formations. Conrad divided the Tertiary, in conformity with the English custom, into an Upper Marine formation, a Middle Tertiary formation, and a Lower Tertiary formation, and gave the geographic extensions of each so far as they are known.

Hitchcock's Survey of Massachusetts, 1830, 1833, 1841.

In 1830 the legislature of Massachusetts passed a resolve authorizing the appointment of a surveyor to make a general survey of the Commonwealth, and on the fifth of June following, on the recommendation of Governor Lincoln, further authorized the appointment of "some suitable person" to make, in connection with this survey, a geological examination of the region involved. On February 2, 1831, the limits of the geological survey were extended so as to allow the inclusion in the report of a list of the mineralogical, botanical, and zoological productions.

Prof. Edward Hitchcock, then professor of chemistry and natural history in Amherst College, was selected as the "suitable person," and presented, early in 1832, a report of 72 pages, with a colored geological map, on the economic geology of the State. Of this 600 copies were ordered printed. In the early part of 1833 reports on the topographic geology (37 pages), scientific geology (430 pages), and the catalogues of animals and plants, with an appendix containing a list of the rocks and minerals described (248 pages), were likewise submitted.

The legislature promptly accepted these reports likewise and ordered the printing of 1,200 copies, including a reprint of the report first made. Altogether these formed an octavo volume of 692 pages, with numerous figures in the text, and a folio volume of 19 plates, including a colored map. The publication of this report marks an epoch in American geological work, since it brought to a successful conclusion the first survey of an entire State at public expense.[a] It is true that spasmodic beginnings had been made in North and South Carolina, but such were so lacking in breadth of conception and failed so utterly in execution that it is only by courtesy that they can be considered as *geological* surveys at all. Under these conditions a detailed review of the contents of the reports will not be out of place here.

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[a] The total expense to the State of the three years' work, exclusive of cost of printing, was $2,030.

In the consideration of the application of Beaumont's theory of mountains to those of Massachusetts, Hitchcock thought to find six systems of strata and contemporaneous uplift in the State. These six systems as enumerated are: (1) The oldest meridional system, (2) the trap system, (3) the latest meridional system, (4) the northeast and southwest system, (5) the east and west system, and (6) the northwest and southeast system.

The Hoosac Mountains, considered under his oldest meridional system, he regarded as due to two different epochs of elevation, the last taking place after the deposition of the new red sandstone, as was shown by the slight dip (15° to 20°) of the latter, while the slates and gneisses of the range stand nearly vertical. The force which gave rise to mountain uplift he regarded as gravity acting on the crust as the nucleus gradually shrunk away in process of cooling.

Not the least interesting chapters in Hitchcock's work are those relating to the unstratified rocks. Here, under the name of *greenstone*, he included the entire series of basic and intermediate eruptives now classed as melaphyrs, diabases, and diorites. Their mineral composition was stated, however, as hornblende and feldspar, though the mineral identified as hornblende has been proven by modern microscopic methods to have been almost wholly augite. Columnar, compact, amygdaloidal, and porphyritic varieties were recognized.

Concerning the igneous origin of these rocks he professed little doubt, and he accounted for their appearance in the form of continuous sheets on the assumption that they were poured out, not from craters but from linear openings produced by the shrinkage of the earth's interior. Thus early was recognized the phenomena of fissure eruptions, as later developed by Geikie and others.

Commenting on the occurrence of the greenstone in "veins," as at Nahant, he expressed the opinion that the slate in which these veins occurred could not have been solid at the time of the intrusion, this on account of the size of the fissures, which seemed to him to be too wide to have been formed by desiccation. Evidently the possibility of the formation of these fissures by dynamic agencies acting on consolidated materials was not then realized.

Under the name of *porphyry* he included the compact eruptive rocks now classed mainly as aporhyolites or quartz porphyries, such as form the cliffs at Marblehead, and are also found in other localities, as Hingham and Malden. Their porphyritic structure he thought could result only from igneous solution. The base of these porphyries he stated to be of compact feldspar, which he regarded as formed by the melting down of preexisting feldspathic rocks.

The slaty structure sometimes shown, and which is now recognized as flow structure, he regarded as representing the original structure of the slaty rock from which the porphyry was derived by fusion.

This view is interesting when compared with those put forward nearly half a century later by one who, working under the misguided T. Sterry Hunt, argued in favor of the sedimentary origin of the entire series.

Hitchcock thought it probable that the mica slate and gneisses of the Hoosac Range passed laterally into one another, owing to a decrease in the amount of feldspar in the gneissic rock. Such a transition seemed to him as possible, whether the rocks were to be regarded as direct crystallizations from aqueous solution or sedimentaries crystallized through the influence of heat. He himself was inclined to the belief that these schists and gneisses were metamorphosed sediments, since he could conceive of no chemical process by which such a variety of minerals as those contained by them could have crystallized out simultaneously from solution. Such a crystallization, he argued, would be differential.

He utilized this same argument in writing on the origin of the granites. These latter he looked upon as resulting from the melting down of other rocks, gneisses being due to the more or less complete fusion and crystallization of feldspathic sandstone. The deeper lying portions, which were most highly heated, gave rise to granitic gneiss, and those further removed gave rise to the porphyritic, lamellar, and schistic varieties. It will be of interest to compare these views with those advanced by Clarence King nearly forty years later.

Hitchcock classed under the name of graywacke the siliceous conglomerate of Dorchester and Roxbury (now considered as of Cambrian age), and, indeed, every conglomerate sandstone and fragmentary formation that was older than the red sandstone and coal formation, thus avowedly following Humboldt.[a]

Under a misapprehension regarding the character of the amygdules, he included under the name of *varioloid wacke* the melaphyr of Brighton and elsewhere, as well as other altered Paleozoic lavas found at Hingham, Needham, and Saugus; also the siliceous or flinty slates of Nahant and jasper of Newport.

The red sandstones of the Connecticut Valley were rightly set down as belonging to the New Red, he having identified the upper portions of the bed with the New Red sandstone of Europe through the presence of "vertebral" remains found at East Windsor, Connecticut, and Sunderland and other localities in Massachusetts. He still, however, thought it not impossible that the lower portion of the beds might correspond to the Old Red sandstone of Europe. It will be remembered that in the American Journal of Science for 1823 he considered these upper beds as belonging to the coal formation, on account of the included thin seams of bituminous coals.

[a] Humboldt's Essay on the Trend of Rocks in the Two Hemispheres appeared in 1822.

The Tertiary formations of the State he divided into two general groups, the most recent being made to include the beds of blue plastic clay alternating with layers of white siliceous sand, and the second division the plastic clays of Gayhead and Nantucket.

Naturally the drift so abundantly distributed over the surface was attributed to the action of the Noachian deluge. "That seen about Cape Ann can not fail to impress every reasoning mind with the conviction that a deluge of tremendous power must have swept over this cape. Nothing but a substratum of syenite could have stood before its devastating energy."

One of the points which must impress the reader who is at all conversant with the work of modern physiographers is the inability of Hitchcock, as well as his contemporaries, to understand the relationship existing between a river and the channel in which it flowed. Discussing the course of the Connecticut River, he wrote: "The ordinary laws of physical geography seem here to be set at defiance," and "the geologist will be surprised to find it crossing the greenstone ridge" at its highest part, i. e., through the gorge between Mounts Holyoke and Tom. The facts that he deduced from this and other like illustrations are that "surely the Connecticut River did not excavate its own bed, but the gorges through which it and the Deerfield and Westfield pass were excavated to a considerable depth before they began to flow."

The student of to-day need scarcely be reminded that the river did excavate its own channel and ran in essentially its present position before the warping which brought the trap ridge across its course took place.

Hitchcock was not a believer in the doctrine of uniformitarianism; indeed, while perhaps not an extreme catastrophist, he combated vigorously the views put forth by Lyell in his Principles,[a] and argued for the greater intensity of geological agencies in the earlier periods of the earth's history. Some of his reasons for this belief are worthy of attention. He believed the continent to have been elevated above the ocean, not little by little, but by a few paroxysmal efforts of volcanic force. Since this force, as acting during the past four thousand years, seemed too feeble to result in the elevation of a single mountain chain, so, he argued, it must have been more energetic in previous epochs.

The fact that the older rocks are more distorted and highly metamorphosed than the younger was also regarded as indicative of the greater intensity of the earlier productive agencies. Singularly enough, the near-shore origin of beds of conglomerate was not realized, the occasional occurrence of such among sedimentary rocks being regarded as due to the "occasional recurrence of powerful

[a] The first edition of this celebrated work appeared in 1830.

debacles of water," the like of which can not be produced by any causes now in operation.

Concerning the origin of valleys there was manifested a great dearth of knowledge. "I am in doubt whether there is more than one valley in Massachusetts that is, strictly speaking, a valley of denudation," that being the one lying between Mount Toby and Sugar Loaf. The valleys in Berkshire and Worcester and possibly also that of the Merrimac River were regarded as primary, more or less modified by deluges and other abrading agencies.

Accompanying this report was a volume of nineteen plates, comprising a colored geological map of the State; nine general and special views; four of fossils; a map of the valley of the Connecticut; a map showing the direction of the strata; two plates of sections, three of which ran in an east and west direction and one in a north and south; and one "tabular view" of the rocks and their imbedded minerals.

On the map the rocks were colored as belonging to six groups, as below. It will be noted that there is no attempt at other than a lithological classification until the New Red sandstone and Tertiary are reached.

1	1. Granite. 2. Syenite. 3. Greenstone. 4. Porphyry.
2	5. Gneiss. 6. Hornblende slate associated with gneiss. 7. Quartz rocks associated with gneiss.
3	8. Mica slate. 9. Quartz rock. 10. Talcose slate. 11. Chlorite slate. 12. Hornblende slate.
4	13. Limestone. 14. Scapolite rock.
Miscellaneous	Steatite. Serpentine.
5	15. Grauwacke. 16. Argillaceous slate. 17. New Red sandstone.
6	18. Tertiary. 19. Diluvium. 20. Alluvium.

Deposits and mines of useful minerals were noted, among them being plumbago, coal, peat, lead, iron, copper, and manganese.

The drawings of fossils and the general views were the work of Mrs. Hitchcock.

In 1837 Doctor Hitchcock was commissioned by Governor Everett to make a further geological and mineralogical survey in which economic problems should be of primary importance. His report appeared in the form of House Document No. 52, under date of 1838. In 1839 the legislature authorized the reprinting of all the reports, with such additions and corrections as the author chose to make. This reprint appeared in 1841 in the form of two quarto volumes of 831 pages, the first 126 of which are given up to a discussion of the soils, their kind, origin, and fertility.

Hitchcock here followed closely Sir H. Davy, Berzelius, and S. L. Dana, and dwelt particularly upon the problematic geine, a substance resulting from vegetable decomposition and supposed to contain all the essentials of plant food. This part of the work is of interest as containing C. T. Jackson's expressed and well-founded doubt as to the existence of such a body, and a long letter from S. L. Dana attempting to prove the chemical unity of the compound. Some twenty pages were devoted to fossil fuels, with especial reference to the anthracite of Worcester, Massachusetts, and of Rhode Island, and the bituminous coal of the New Red sandstone. A list of peat bogs, with reference to their possible availability for fuel, was also given. Building stones were discussed, and two pages devoted to the subject of rock decay and its probable cause. Metallic and nonmetallic ores were described.

Many of the views expressed in the early reports were repeated here with but slight modification. He still adhered to his six distinct systems of strata which were tilted at various epochs. The oldest, called the meridional system, embraced all the primary rocks lying between the valleys of the Connecticut and Worcester. The second, or northeast and southwest system, included the gneiss range in the southeastern part of Worcester County, the central part of Middlesex, and a part of Essex. The third, or east and west system, included the gneiss around New Bedford, the graywacke, and a large part of the syenite, porphyry, and greenstone of the State. The fourth, or Hoosac Mountain system, embraced all the rocks between the Connecticut and Hudson rivers, except the trap and New Red sandstone. The fifth included the New Red sandstone, and the sixth, or northwest and southeast system of rocks, mainly gneiss occurring in the southern part of the State bordering upon Rhode Island. In the geological map which accompanied this report he employed but six colors, which marked off the rocks of the State into six distinct groups, the members of each of which, with the exception of the fourth, were so nearly related that he thought they might be regarded as belonging to the same formation. In his first group he placed the granite, syenite, greenstone, and porphyry; in the second, gneiss and the associated hornblende slate and quartz rock; in the third, mica slate, with the associated quartz rock and hornblende slate, talcose slate, and chlorite slate; in the fourth, limestone, steatite, and serpentine; in the fifth, metamorphic slates, graywacke, argillaceous slate, coal measures, and the New Red sandstone, and in the sixth group, Eocene Tertiary, diluvium, and alluvium.

Hitchcock described the Connecticut as flowing through a synclinal valley, a valley which became nearly filled by the red sandstone deposit. This last, he thought, had since been eroded away, so that the valley as it now exists may "in some sense" be considered "as a valley of denudation." Most of the valleys in Massachusetts he still regarded as valleys due "to the elevation and dislocation of the strata."

He noted that the animal remains found in the older rocks differed the most radically from the existing species, and also that the organic remains found in northern portions of the globe corresponded more nearly to existing tropical species than did those now living in the same localities. Further than this, he announced that different species, genera, and families of animals began their existence at very different epochs in the earth's history, and that the same species rarely extended over from one formation into another. Notwithstanding this, though giving lists of fossils found in rocks of various horizons, he made no attempt to determine their relative ages by means of them and regarded correlation by such aids as impossible. Following Phillips and Lyell in many of his statements, he yet announced as a principle that "Rocks agreeing in their fossil contents may not have been contemporaneous in their deposition," although they might not differ greatly in age. "From all that has been advanced," he wrote, "it appears that an identity of organic remains is not alone sufficient to prove a complete chronological identity of the rocks widely separated from each other; but it will show an approximate identity as to the period of their deposition, and in regard to rocks in a limited district it will show complete identity." Where both the mineral nature and the character of fossils were identical, identity or synchronism would be much more probable, but a want of such agreement, so far as it related to mineral character, was not regarded as fatal to the idea of synchronism.

He argued against the idea that the stratified primary rocks are merely the detrital or fossiliferous rocks altered by heat, but regarded them rather as products of both mechanical and chemical action by aqueous and igneous agencies when the temperature of the crust was very high and before organic beings could live upon it.

He noted that the dolomitic rocks seemed genetically related to the limestones, but his ideas as to the methods by which the changes had been brought about were naturally somewhat crude when considered in the light of to-day. From a study of the field relations of the dolomites of Berkshire County and other localities he came to the conclusion "that all the cases of dolomitization in Massachusetts occur either in the vicinity of a fault, or of unstratified rocks, or in the midst of gneiss, where the evidences of the powerful action of heat in the induration of the limestone and the obliteration of its stratification is as great as results from the presence of unstratified rocks." The actual dolomitization he thought to have been "probably produced by gaseous sublimations, chiefly of carbonate of magnesia, which penetrated the rock after it had been softened by heat so as to be permeable.[a] In some instances, however, he thought it highly probable that magnesian limestone had been deposited directly from thermal waters.

In seeking an explanation of the fact that in passing from the top of Hoosac Mountain toward the Hudson River one continually meets newer and newer rocks which always appear to pass under the older—in other words, that there is inversion of the strata—he came to the conclusion, put forward with some hesitation, "that these rocks have actually been thrown over into an inverted position, or rather, have been so contorted by a force acting laterally that one or more folded axes have been produced."

The same feature had been mentioned in his report for 1835, but then appeared "too improbable to be admitted." His views on the subject were illustrated by a sketch, copied in fig. 22; the portion above the heavy continuous black line being conceived to have been removed by erosion. Later this observation was claimed to be the first recognition of the true character of overturned folds. This was, however, disputed by H. D. Rogers, who claimed to have made and published similar observations during the progress of the New Jersey survey in 1838–39.

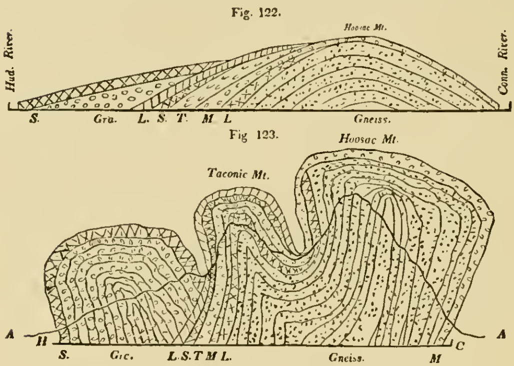


FIG. 22.—Folded axes. (After E. Hitchcock.)

Below is the paragraph upon which the claim of Rogers was apparently based. The statement is made in the course of a description of the various axes of elevation that have given rise to the more prominent physical features of northern New Jersey.

> The movement which elevated Jenny Jump, seems to have been everywhere one of excessive suddenness and violence, as the strata along its anticlinal axis are not only frequently much dislocated and broken, but those lying immediately along its northwestern base are in several places thrown into an inverted posture, dipping not to the northwest, but in toward the base of the hill.[b]

[a] This is probably a reflection of views earlier put forward by Von Buch with reference to the dolomites of the Tyrol.

[b] Geology of New Jersey, 1840, p. 55.

The idea was, however, brought out much more clearly in a communication made by him before the Association of American Geologists and Naturalists in 1841, an abstract of which was given in their Proceedings and in the American Journal of Science for the same year. He then called attention to the "inverted dip" observable among the rocks of the Coal Measures (of Pennsylvania) and ascribed the same to a great force acting laterally, folding and crushing the axis so as to produce this inverted dip by tossing the strata many degrees beyond the perpendicular, thus producing the present apparent dip of the lower stratified or sedimentary rocks beneath the primary.

In view of the observations made by Eaton in 1820, Steel, in 1825, and W. B. Rogers, in Virginia, in 1838, as noted elsewhere, the subject of priority between the two first named is scarcely worth discussing.

Heavy demands have from a very early time been made upon electric currents to account for all sorts of geological phenomena, from the formation of ore deposits to the production of slaty cleavage, or even the uplifting of mountain ranges. It is not strange, therefore, that Doctor Hitchcock should have felt justified in making slight draft upon it to help him over some of his minor difficulties. The peculiar imitative and otherwise interesting forms assumed by the ferruginous concretions found in the Connecticut Valley demanded an explanation. "I know of no agent," he wrote, "that could have accomplished this (i. e., the separation of the iron from the menstruum which held it in solution) except galvanic electricity," and again, "I strongly suspect galvanism to have been a chief agent in concretions of every sort."

In the report of 1833, and again in those of 1835 and 1841, Hitchcock called attention to the peculiarly flattened and otherwise distorted pebbles in the conglomerate at what is locally known as Purgatory, near Newport, Rhode Island. His description is important in view of his subsequent writings and the discussions which arose in connection therewith. The subject may, however, well go over until his later paper of 1861 (see p. 510).

This final report, coming at the time it did, naturally attracted much attention and favorable comment. From a brief preliminary review in the American Journal of Science the following paragraph is selected:

> If we reflect that the vast mass of facts and information of various descriptions, and the reasonings and inferences contained in these columns, are all the result of untiring, nay, almost Herculean, efforts of an individual mind, continued among the harassments of constant professional duty during a period of ten years, we are encouraged to hope that we may yet see the day when the united efforts of our small army of working geologists now laboring in the common cause shall reduce the whole of our widespread territory to an intelligible perfect system.

Although our sketches have thus far been confined largely to Americans, either by birth or adoption, the times with which we are now dealing will scarcely permit us to overlook the explorations of Jean N. Nicollet throughout the Middle West.

Sketch of Nicollet.

Nicollet was born in France in 1790 and came to America in 1832 from purely financial considerations, having involved not merely his own fortune but those of friends in unfortunate speculations. His main scientific work up to this date had been of an astronomical nature, and it is perhaps natural that his attention in a new country should have turned toward exploration and map making.

Nicollet's Work in America, 1833.

From 1833 to 1838 he was engaged, with the cooperation of the War Department, though without financial assistance, in mapping the region of the upper Mississippi. From 1838 to 1841 he was in the employ of the Government, completing the surveys and maps thus begun. Other work of like nature was projected, but before plans were matured his health gave way and he died in 1843. His geological work, under the conditions mentioned above, was therefore of comparatively slight importance, excepting as calling attention to regions as yet but little explored.

He claimed to have traced the Cliff limestone of Owen over a vast extent of country in the Mississippi Valley, and connecting his own work with that of Owen, Locke, H. King, and others, felt justified in assigning the Falls of St. Anthony as the northern limit of the formation. In this he was correct. He added to the knowledge of the geology of the region of the Sioux and Missouri rivers by bringing in important Cretaceous fossils, both vertebrate and invertebrate in their nature; described the occurrence of the Indian pipestone (Catlinite) of the Coteau des Prairies of Minnesota, and correctly described the pseudovolcanoes and their pumice-like product as due to burning lignite beds.

The second American edition of Bakewell's Geology, from the fourth London edition, was printed, as was the first, in New Haven and under Silliman's supervision. The work needs notice here, as it shows Silliman's gradually expanding views and disposition to shake off the shackles of tradition, though still floundering in the deep waters of the Noachian deluge. Of particular interest are his remarks on the nature of geological evidence and its consistency with sacred history.

Second American Edition of Bakewell's Geology, 1833.

Silliman took the ground that there was no reason to believe that any part of the crust of the earth is now in the same condition as first created, every portion having been worked over in accordance with physical laws which are as much the Creator's work as are the materials upon which they operate. Unlike some of his predecessors and contemporaries, he did not, however, at this time feel it incumbent upon him to close his eyes to, or even to distort, any evidence that might present itself in order that it might not conflict with the statement of sacred history. "Any attempt to disprove the truth or genuineness of the Pentateuch, and Genesis in particular, is wholly superfluous, and quite aside from any question that can in this age be at issue between geologists." "No geologist at the present day erects any system upon the basis of the scripture history." But admitting that the Mosaic history is genuine and true, he felt that one might with historical and philosophical propriety compare geology with history and regard historical coincidence with observed phenomena as interesting, "because they are mutually adjuvant and confirmatory." As with other workers, including even some of the present time, he found most that is confirmatory in a study of the drift or "diluvial," which was naturally ascribed to torrential action, and perhaps concomitant with the universal deluge recorded in Genesis. After a somewhat prolonged discussion of the meaning of the term "days," as used in Genesis, he gave the following:

Table of coincidences between the order of events as described in Genesis and that unfolded by geological investigations.

In Genesis.	No.	Discovered by geology.
Gen. I. 1, 2. In the beginning God created the heavens and the earth. And the earth was without form and void; and darkness was upon the face of the deep; and the Spirit of God moved upon the face of the waters.	1	It is impossible to deny that the waters of the sea have formerly, and for a long time, covered those masses of matter which now constitute our highest mountains;
3, 4, 5. Creation of light. 6, 7, 8. Creation of the expansion or atmosphere. 9, 10. Appearance of the dry land.	2	and, further, that these waters, during a long time, did not support any living bodies.—Cuvier's Theory of the Earth, sect. 7.
11, 12, 13. Creation of shooting plants, and of seed-bearing herbs and trees.	3	1. Cryptogamous plants in the coal strata.—Many observers. 2. Species of the most perfect developed class, the Dicotyledonous, already appear in the period of the secondary formations, and the first traces of them can be shown in the oldest strata of the secondary formation; while they uninterruptedly increase in the successive formations.—Prof. Jameson's remarks on the Ancient Flora of the Earth.
14 to 19. Sun, moon, and stars made to be for signs and for seasons, and for days, and for years.		

Table of coincidences between the order of events as described in Genesis and that unfolded by geological investigations—Continued.

In Genesis.	No.	Discovered by geology.
20. Creation of the inhabitants of the waters.	4	Shells in Alpine and Jura limestone.—Humboldt's tables. Fish in Jura limestone.—Humboldt's tables. Teeth and scales of fish in Tilgate sandstone.—Mr. Mantell.
Creation of flying things.	5	Bones of birds in Tilgate sandstone.—Mr. Mantell, Geological Transactions, 1826. Elytra[a] of winged insects in calcareous slate, at Stonesfield.—Mr. Mantell.
21. The creation of great reptiles.	6	It will be impossible not to acknowledge as a certain truth the number, the largeness, and the variety of the reptiles which inhabited the seas or the land at the epoch in which the strata of Jura were deposited.—Cuvier's Ossem. Foss. There was a period when the earth was peopled by oviparous quadrupeds of the most appalling magnitude. Reptiles were the lords of creation.—Mr. Mantell.
24, 25. Creation of the mammalia.	7	Bones of mammiferous land quadrupeds, found only when we come up to the formations above the coarse limestone, which is above the chalk.[b]—Cuvier's Theory, sect. 20.
26, 27. Creation of man........	8	No human remains among extraneous fossils.—Cuvier's Theory, sect. 32. But found covered with mud in caves of Bize.—Journal.
Genesis, VII. The flood of Noah, 4,200 years ago.	9	The crust of the globe has been subjected to a great and sudden revolution, which can not be dated much farther back than five or six thousand years ago.—Cuvier's Theory, 32, 33, 34, 35, and Buckland's Reliq. Diluv.

[a] Sheaths.
[b] One solitary exception is since discovered, in the calcareous slate of Stonesfield, in the bones of a didelphis, an opossum, a tribe whose position may be held intermediate between the oviparous and mammiferous races.

Perhaps that part of Professor Silliman's work which showed the keenest insight into geological problems is that relating to the subject of crystallization in rocks. The proximate causes of the phenomenon were recognized as heat and solution.

There is no doubt that fire and water * * * have operated in all ages in producing mineral crystallization. Of these, however, fire appears to have been by far the most active, * * * and there is every reason to admit that even granite has been melted in the bowels of the earth, and therefore may crystallize from a state of igneous fusion. If this be true of the proper crystals of granite it may be also true of the imbedded crystals which it contains, and therefore of all other crystals. Those which contain much water of crystallization may present a serious difficulty, but perhaps pressure may have retained the water, and as the parts of the mineral concreted in cooling the molecules of water may have taken their place in the regular solid. Still we can see no reason for excluding water and other dissolving agents, acting with intense energy under vast pressure and at the heat of even high ignition, from playing a very important part in crystallization. (Pp. 433–434.)

This, it will be observed, is essentially the aqueo-igneous theory of eruptive rocks, and could scarcely be improved on to-day. In this connection it is well to remember that Edward Hitchcock, in his Geology of Massachusetts, 1833 (see p. 309), inferred the igneous origin of granite from its crystalline structure, "since substances held in solution always crystallize in succession, while in granite we have a solid crystalline mass of three or four distinct substances which evidently crystallized contemporaneously."

The tendency to generalize on insufficient data is evidently inherent in the human race, and it was to be expected that it should early make its appearance in so promising a field for speculation as geology. It was therefore not surprising that Eaton, after his many years of study in the eastern United States, should have ventured opinions concerning the little-known West. Basing his statements on observations made by a Mr. John Ball, at one time a student of his, he wrote in 1834:

Eaton's Notions Regarding the Rocky Mountains, 1834.

The geology of the country west of the Rocky Mountains is remarkably simple and uniform. The general underlying rock is the red sandstone, which some English geologists call Saliferous rock, and which characterizes the red sandstone group of De La Beche. It is the same which contains the salt springs of the western part of the State of New York, and which underlies the basaltic rocks (greenstone trap) of Connecticut and Hudson rivers. * * * Wherefore the geology of the east and west sides of the Rocky Mountains is remarkably alike. Mr. Ball says the Rocky Mountains rises up from the midst, as it were, of a horizontal sea of red sandstone, as if some tremendous force had driven it upward, like an island forced up from the depths of the ocean. * * * Mr. Ball considers almost the whole country as volcanic * * * near the west side of the Rocky Mountains. * * * Mr. Ball found first graywacke and sparry lime rock. But he soon entered upon the red sandstone region, which continues as the basis rock to the Pacific. * * * The country is often very mountainous along the route to the Pacific, but the mountains are red sandstone, grey pudding stone, or basalt. Such is the simplicity and uniformity of the geology of the vast region west of the Rocky Mountains that it can all be told in one sentence of six lines.

It may be well to add that Mr. Ball himself took exception to some of the conclusions drawn by Professor Eaton, and later published in the same journal his own views on the subject. These may, however, be passed over here without comment.

The two most important original contributions of the year 1833 were Hitchcock's Massachusetts, already noted, and Isaac Lea's Contributions to Geology, the latter dealing with the Tertiary of Alabama, Maryland, and New Jersey. In Lea's work there were brought prominently forward for the first time, by an American writer, the striking changes that had taken place in the introduction of the Tertiary fauna and the close relationship existing between that fauna and the fauna of the present day.

Lea's Contributions to Geology, 1833.

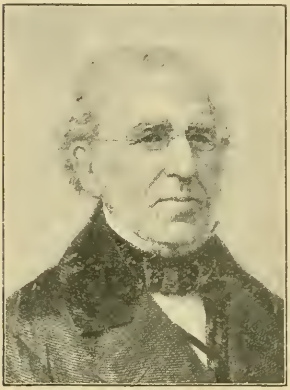


Fig. 23.—Isaac Lea.

Out of some two hundred and fifty species of invertebrates found by Doctor Lea in the bluffs at Claiborne, Alabama, two hundred and nineteen were not referable to any known species, i. e., were not found in any of the beds older than Tertiary and were new to science. It was in this work also that the undoubted presence in America of beds referable to the Eocene of Lyell was recognized, although the character of the fossils and the general position of the beds had been already noted by Conrad (p. 307).[a]

The last named, the year following, marked out the distribution of the Eocene in Maryland and noted the occurrence of Pliocene fossils overlying it at Vance's ferry on the Santee River. The Fort Washington beds, formerly regarded by him as Eocene, he now suggested to be more recent than Lea's Claiborne beds, and perhaps contemporaneous with the Miocene of Europe.

Conrad on the Distribution of the Eocene, 1834.

In 1834 there was organized the Geological Society of Pennsylvania. According to its constitution:

> The objects of the society are declared to be to ascertain as far as possible the nature and structure of the rock formations of the State; their connection or comparison with the other formations in the United States and of the rest of the world; the fossils they contain, their nature, positions, and associations, and particularly the uses to which they can be applied in the arts, and their subserviency to the comforts and conveniences of man.

Organization of the Geological Society of Pennsylvania, 1834.

This society continued in existence but four years, but served its apparent purpose in bringing about the establishment, in 1836, of the State geological survey with H. D. Rogers at its head. A single

[a] This publication of Lea's led to a misunderstanding with Conrad, or rather with Conrad's friends, Say and Morton, who felt that Doctor Lea was invading Conrad's rights. Doctor Lea, however, worked only on material he had received from Judge Tait, prior to Conrad's entry upon the field. (See Dall's Determination of Dates of Publication of Conrad's Fossils of the Tertiary Formations. Bulletin of the Philosophical Society of Washington, XII, 1893, pp. 215–240.)

volume, in two parts, of "Transactions," numbering upward of 400 pages, tells the story of its brief existence. This contains papers by authors now for the most part little known. R. C. Taylor wrote on fucoids and the coal fields of Pennsylvania and Virginia, his papers being accompanied by numerous sections; James Dickson had an Essay on the Gold Region of the United States, all comprised within the limits of 16 pages; Jacob Green had a paper on a Sulphated Ferruginous Earth, and a Description of a New Trilobite from Nova Scotia. Others were by Richard Harlan, Gerard Troost, Thomas Clemsen, and H. Koehler. Few of the writers or active members achieved other reputation than that given by the single publication, though Taylor became an authority on coal, while Harlan and Troost became later widely known, the one as a vertebrate paleontologist and the other as a geologist. This society, it is well to note, was the second geological society to be organized in America, the first being that at New Haven in 1819.

William Aiken's Ideas on Mountain Uplift, 1834.

A brief paper by William Aiken, professor of natural philosophy and chemistry in Mount St. Mary's College, Maryland, published in the American Journal of Science at this time, is worthy of some consideration as bearing upon the prevailing theories regarding mountain uplift and incidental phenomena. Professor Aiken wrote on the geology of the country between Baltimore and the Ohio River, and gave a section showing the inclination and kinds of rocks.

The classification conformed with that prevailing at the time, the rocks being divided into (1) a primitive series in the immediate vicinity of Baltimore, (2) the transition slates, sandstones, and conglomerates of the adjacent county, and (3) the lower secondary rocks of the West.

Noting the reversal of the dip existing between Hancock and Cumberland, he wrote: "Beneath this space, then, we are authorized, in concluding, the eruptive power that was instrumental in upheaving the Appalachian chain was most energetically exerted. This may be considered the true anticlinal region." He regarded the agent so efficient in throwing up mountain chains as igneous, "an opinion that gains confirmation, if any is needed, from the occurrence of thermal waters along the center line of the Allegheny region." It is apparent from this that he agreed with Daubeny and other European geologists as to the volcanic origin of these springs. Roger's paper, ascribing them to the other causes, did not appear until eight years later (see page 372.)

Ducatel and Alexander's Survey of Maryland, 1834.

In accordance with a resolution passed by the general assembly of Maryland, February 25, 1834, J. T. Ducatel, geologist, and J. H. Alexander, a civil engineer, were appointed to make a geological survey and new map of the State. This survey continued in existence until 1840, during which time three annual reports, one on the outlines and physical geography of

Maryland, one on the new map of Maryland, and one on the Frostburg coal formation, were issued, the latter, however, not being an official publication.

The geological reports were given up largely to a discussion of economic matters, such as the character of the soil and the occurrence of coal and ores of the metals. In the report for 1833 the occurrence of fossiliferous deposits in Prince George County; at Maryland Point, in Charles County; and on St. Mary's River, in St. Mary's County; also at Fort Washington on the Potomac, were noted, but none of the fossils were identified nor any suggestion made as to their probable geological age, although that portion of Maryland was later referred to as being occupied by Tertiary rocks. The rocks comprising the upper part of Cecil County, the greater portion of Baltimore and Harford counties, the upper districts of Anne Arundel County, and the whole of Montgomery County, were thought to be generally metalliferous and were grouped as primary or primitive. The serpentinous rocks were looked upon as of importance, as likely to furnish the basis for the manufacture of epsom salts, a not uncommon opinion at that time. On the map prepared under the direction of Mr. Alexander the lithological nature of the underlying rocks and the character of the soil were indicated by names, no attempt being made at coloring.

In 1835 Ducatel visited the Eastern Shore of Maryland and in his report for that year gave a very full account of the geography and agricultural condition of Dorchester, Somerset, and Worcester counties. He announced the presence there of considerable deposits of greensand marl, which he believed would be of great value to the agriculturist. In 1836 he completed the geological survey of Calvert County and made extensive examinations in Anne Arundel, Prince George, Charles, and St. Mary's counties, where he found further deposits of marl. In this same year he examined the coal and iron deposits of Allegany County and published a geological account and section of the beds.

In his report for 1838 he gave a general account of the mineral resources of Harford County and outlines of the geology of Harford and Baltimore counties, with a short treatise on the subject of lime burning.

This survey was regarded by Ducatel as being the first attempt to connect a topographic and geological survey.

Sketch of Ducatel.

Ducatel was born in Baltimore, where his father, a Frenchman, conducted for many years a prominent pharmaceutical establishment. He received his early training at St. Mary's College in Baltimore, subsequently studying in Paris. In 1824 he returned to America, and shortly after entered upon a very successful career as a teacher of the sciences—chemistry, philosophy, mineralogy, and geology—serving in the Mechanic's Institute and the University of Maryland in Baltimore, and St. John's College in Annapolis.

In order that he might devote himself more fully to the work of the survey, he severed his connection with the institutions of learning about 1838. The move, however, proved an unfortunate one, as the survey was shortlived and he was thrown back upon his own resources.

Fig. 24.—Julius Timoleon Ducatel.

In 1846 he visited, in the capacity of a geological expert, the Lake Superior mining regions. Through exposure while there he contracted a severe illness, which left him in an enfeebled condition from which he never fully recovered. He died from congestion of the lungs in 1849.

Ducatel is represented to us as a man of generous traits and of winning character, ardent and enterprising. Physically he was short in stature, with square shoulders, black eyes, dark complexion, and face strongly pitted by smallpox. He bent forward and walked with a nervous, energetic step, which betokened the ceaseless activity of one accustomed to work and think for himself.

Few publications bear his name, though as a writer for the journals of the day he is said to have been quite prolific. His principal work was a Manual of Toxicology, which, it is stated, was well received.

Featherstonhaugh's Survey, 1834.

In July, 1834, G. W. Featherstonhaugh, who was introduced to the reader on page 301, was authorized by Lieut. Col. J. J. Abert, acting under instructions of the War Department, to make a geological and mineralogical survey of the "elevated country lying between the Missouri River and Red River, known under the designation of the Ozark Mountains."[a] The survey was duly made and a report rendered bearing the date of February 17, 1835. This comprised altogether 97 pages, the first 42 of which were given up mainly to a discussion of general principles not germane to the report at all, but which, as indicating the condition of mind of the writer, are worthy of consideration. He regarded the continents and islands as having originated through an expansive subterranean force, and believed the mineral veins to have been filled from below, rather than from above, as taught by Werner.

Granite was regarded as an igneous rock, and designated as "ignigenous." Gneiss he recognized as often passing into granite, while some of the primary limestones he thought to have possibly "come from central parts of the earth, in a state of aqueous solution, and to have subsequently received their high crystalline character from being in contact with ignigenous rocks in an incandescent state." To the com-

[a] This appears to have been the first formal recognition of the science of geology by the General Government.

monly received opinion, that all coal resulted from vegetable matter, he took exception, and thought that some beds "may have been the result of outpourings of bituminous matter." The wide geographical distribution of Carboniferous rocks west of the Appalachians and in the Mississippi Valley was noted, and a section given comprising 1,520 vertical feet of these rocks and overlying shale and millstone grit, at Burkesville, Kentucky.

Passing to the specific part of the work, Featherstonhaugh discussed the occurrence of the lead ore (galena), its distribution in loose pieces in the soil, and its relation to the vein material in the solid rock, but the fact that this superficial layer was but the detritus from the decomposition of the underlying rock does not seem to have been realized more than by his predecessors. He remarked, however, that the disseminated granules in the limestone, as at Isle La Motte, furnished to the eye "sufficient proof that the stony and metallic matter were deposited at the same time," an idea not altogether different from that held to-day. Further on he noted the occurrence of the ore in pockets or cavities filled with red clay as pointing "to a projection of this metallic or mineral matter from below."

He described the hematite deposit of Pilot Knob, Missouri, and correctly noted the improbability of finding precious metals in Arkansas in paying quantities. Magnet Cove he regarded as having been perhaps "one of those extremely ancient craters that may have preceded those of which basalt and lava are the products."

Although Featherstonhaugh's standing with his fellow-geologists does not seem to have been the best, some of his recorded observations certainly show a more philosophical mind and greater ability to grasp the broader problems of geology than do those of many of his contemporaries. Thus, discussing the muddy character of the Mississippi, he suggested that experiments might be conducted to show the amount of sediment annually brought down, whereby we might approximately assign a chronological period for the origin of the river, the commencement of the alluvial deposits, and the withdrawal of the ocean. This, so far as the present writer is aware, is the first suggestion of its kind to be made.

Commenting on the fact announced by him in 1828 and since confirmed, that, with the exception of the Tertiary and sub-Cretaceous beds of the coast, no rocks more recent than the coal-bearing series had been found in the United States, he suggested that the American continent might in reality be older than the European. This also is the first suggestion of its kind to be found in our literature.

The report was accompanied by a colored geological section extending from the Atlantic at New Jersey to the Red River in Texas. On this all New Jersey and Delaware as far as Chesapeake Bay were colored as occupied by superficial sand and sub-Cretaceous beds; Maryland to the west of the Potomac mainly by primary granites, gneiss, and slate, with a narrow band of transition limestone; Virginia by transition limestone overlaid in part by graywacke; Tennessee by graywacke overlaid at the Cumberland Mountains by Carboniferous limestone; Kentucky, Indiana, and Illinois by Carboniferous limestone; Missouri and Arkansas by Carboniferous limestone capped by calcareo-siliceous hills, and Arkansas, from a point about midway between the Fourche and Arkansas rivers, by graywacke capped by Old Red sandstone and occasional Tertiary deposits, with sub-Cretaceous beds beginning again at the Caddo River and extending nearly to the Red River in Texas, where they were covered by a ferruginous sandstone. It was a reprint of this section in the Transactions of the Geological Society of Pennsylvania that Lesley referred to in his Historical Sketch of Geological Explorations as "a rambling description and a worthless geological section across the continent from New York to Texas."

In 1835 Featherstonhaugh, again under instructions from Lieutenant-Colonel Abert, made a geological reconnaissance of the region lying between the seat of government and the Coteau des Prairies, by way of Green Bay and the Wisconsin Territory. His report, issued in 1836, formed Senate Document No. 333, comprising 168 pages, with 4 plates of sections and diagrams. In this, as in his first, there is a large amount of preliminary matter of a very general nature. He noted that Washington and Georgetown were underlaid by gneiss, in which were perceived evidences of an "extensive anticlinal movement by which all the rocks along the entire length of the Potomac," as high up as the great bituminous field, had been affected, and that the true dip of the rocks was often "contradicted by the cleavage." This was a by no means unimportant observation. The erosive action of the river, as manifested by potholes in the schists at Great Falls, was dwelt upon and the Seneca sandstone and Potomac breccia described, the former noted as often carrying anthracite and casts of calamites, but no suggestion as to the geological age of the beds was given. The Catoctin Mountains were described as "composed of primary slates, sandstones, and quartz having a northeast direction." Referring to the relationship existing between the Potomac breccia and the limestones, slates, and shales, he wrote:

> We thus have all the proofs that the Atlantic primary chain has come up from below through the limestone, triturating and breaking it up into fragments of every size, which were subsequently transported to the east of the chain by a current from the west, and deposited there, intermixed with the decomposed red shale.

He concluded, therefore, that the Atlantic primary chain was elevated posterior to the deposition of the limestone, "which may be considered the equivalent of the lowest beds of Mr. Murchison's Silurian rocks." The unsymmetrical character of the folded sandstones and grits at Wills Creek, in Maryland, he described as affording evidence "that all the beds had been bent up by some action from below, and that from some inequality in the action or from some external cause the bed on which they lay, together with its associated strata, had collapsed toward the center in such a manner that they would appear to have been thrown up into a vertical position, if the uncurvated part had been concealed."

In remarking on the constancy of the phenomena connected with the anticlinal arrangement of the whole series of Allegheny ridges, he ascribed their origin to an elevatory undulating movement, whereby "some parts of the strata were forced up into the anticlinal form, in a constant magnetic direction," the intervening distance between each axis or ridge being at the same time probably thrown down in a ruinous state. As the land arose and the waters retired the ruins would gradually be borne away, leaving the valleys as we now find them.

The extensive bituminous coal beds of Maryland and Pennsylvania were described, the coal itself considered as due to plant growth in situ, and not to drift.

The presence of Carboniferous limestone about 8 miles from Navarino, Wisconsin, was noted and also, but erroneously, at the Falls of St. Anthony, in Minnesota. The lead-bearing beds of Dubuque, Iowa, were also judged, by their fossils, to be Carboniferous. In this, also, he was in error.

Rogers's Survey of New Jersey, 1835.

In 1835 there was organized under the authority of the legislature of New Jersey a State geological survey, of which Prof. H. D. Rogers was made chief. The survey continued until 1839, the final report, a volume of some 300 pages and a colored geological map, bearing the date 1840, the first annual report being issued in 1836. In this final report Rogers argued that nearly the whole surface of the region occupied by the counties of Middlesex, Monmouth, Burlington, Gloucester, Salem, and Cape May was at some former period upon a level with the top of the surrounding hills, as shown by the finding of sandstone strata always at about the same elevation and in the horizontal position in which it was deposited. These hills he regarded as hills of denudation, that is to say, as formed by the washing away or laying naked of the strata which formed the surface of the region about them; but, looking at the matter, as he did, through the eyes of a catastrophist, he was unable to say "from what quarter the mighty rush of waters proceeded which swept off so extensive a part of the upper rocks."

In view of the great difference of opinion which has existed and still exists in the minds of geologists regarding the age of the white limestone near Franklin Furnace, New Jersey, it is not without interest to note that Rogers himself regarded it as having been originally the blue limestone of the district invaded at some period by mineral veins in a highly heated or molten state, whereby was effected a series of changes similar to those known to be caused by injections of trap into similar strata.

In his final report Rogers divided the rock formations of the northern division of the State into, first, a group of primary rocks confined to the islands and the vicinity of Trenton; second, a group of older secondary strata confined to the northwestern portions of Sussex and Warren counties, and third, a group of middle secondary strata lying in the broad belt of country between the southeastern foot of the Highlands and the boundary connecting Trenton and New Brunswick. With this third group he also connected the trap rocks of the region.

The occurrence of graphite in the altered rocks near Sparta, remote from igneous dikes, and its nonoccurrence in more than very trivial quantities adjacent to the dikes, he looked upon as strongly implying that it had been derived "from the elements of the blue limestone itself, which may easily be proved to contain an adequate quantity of iron and carbon for the production of this mineral."

The great thickness throughout which this limestone had undergone crystallization, apparently from the heating agency of the dikes which traversed it, and the law which he traced in the development of some of the minerals, afforded, as he felt, unquestionably strong support to the theory that gneiss and other primary strata had once been sedimentary rocks, converted by an intense and widespread igneous action into a universally crystalline state.

The presence of carbonate of copper diffused throughout the fissures of the shales indicated to his mind that a considerable portion of the metalliferous material, particularly the carbonate, had entered the strata in a gaseous or volatile condition and not in that of igneous fusion. The iron and zinc deposits, on the other hand, were "unequivocally genuine lodes or veins" filled with "matter injected while in a fused or molten state" and not beds formed contemporaneously with the surrounding rock.

Rogers's Views on the Gorge at Niagara, 1835.

It may be recalled that in 1820 Professor Bakewell visited the Falls of Niagara, and on his return to England published in the London Magazine a short memoir, in which he endeavored to show that the falls were once at Queenstown. In the autumn of 1846 he again visited the falls and made the additional observation that the river at one time probably flowed through the ancient gravel-filled valley extending from the Whirlpool to St. Davids. In this subsequent research has shown he was eminently correct. Nevertheless, his observations at the time were not wholly accepted.

In 1834 a Mr. Fairholme, writing in the London and Edinburgh Philosophical Magazine, accepted Bakewell's views as expressed in

1820 and put forward certain of his own relating to the rate of back-cutting of the falls. To these views H. D. Rogers, in the American Journal of Science for 1835, took serious exception. He believed that the channel below the falls had been formed in part as a diluvial valley and by some far-sweeping currents which denuded the entire surface of North America and strewed its plains and mountains with bowlders, gravel, and soil from the north. "The passage of such a body of water over the surface would deeply indent all the exposed portions of the land. Rushing in a descent from Lake Erie to Lake Ontario, from a higher to a lower plain, and across a slope like that at Queenstown, it would inevitably leave a long ravine." Commenting on this, Silliman remarked in the same journal that an earthquake might possibly be instrumental in producing at once such a crack in the strata as would drain the lakes in a few days or hours, and to such an agency might be ascribed the channel in question. (See Hall's paper, p. 384.)

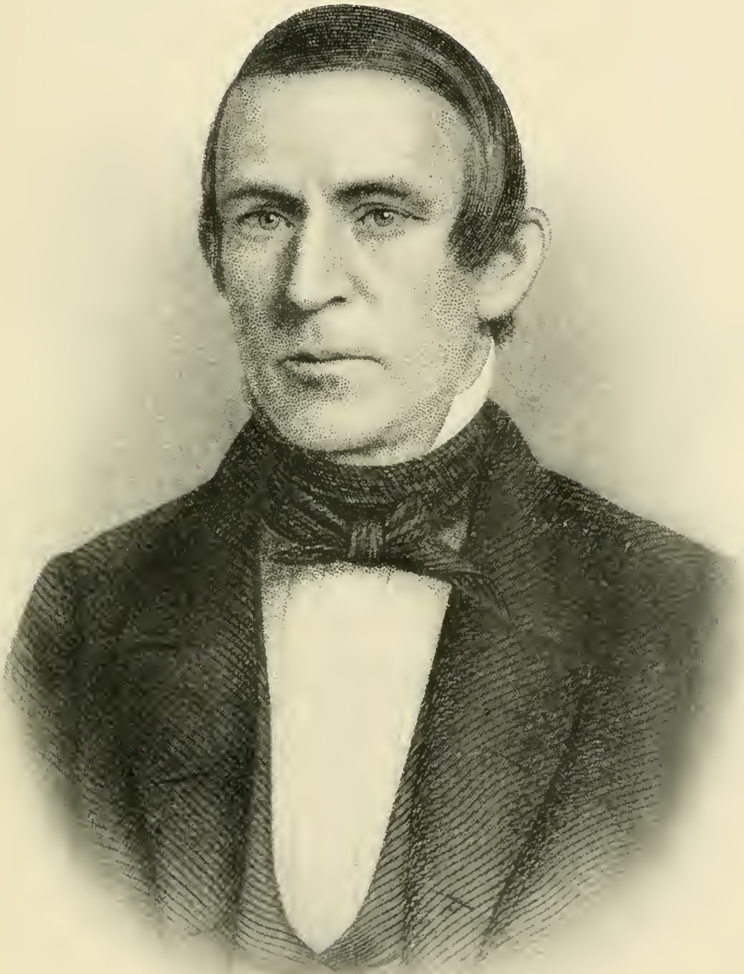
Rogers was born in Philadelphia in 1808, being one of four brothers—James B., William B., Henry D., and Robert Empie—all of whom rose to distinction as geologists or chemists. When not quite twenty-two years of age he became professor of chemistry and natural philosophy in Dickinson College, resigning in 1831 for the purpose of going to Europe to complete his studies. He returned to Philadelphia in 1833, and in the ensuing winter delivered courses of lectures on chemistry in the hall of Franklin Institute.

Sketch of H. D. Rogers.

In 1835 he was elected professor of geology and mineralogy in the University of Pennsylvania, and was also appointed by the legislature in the same year to make a geological survey of the State of New Jersey, as already mentioned. In 1836 he was made State geologist of Pennsylvania, and it is upon the work done in this connection that his fame as a geologist chiefly rests.

In 1857 he was made regius professor of natural history in the University of Glasgow, being the first American to thus receive a foreign appointment. As was the case with his brother, W. B. Rogers, he was a good lecturer, with quiet, gentlemanly bearing, never failing to make a favorable impression upon his audience.

His work in Pennsylvania showed not merely great administrative ability, but also the power of mastering fully the observations of his assistants, making therefrom important generalizations. He was unquestionably the leading structural geologist of his time. That his generalizations and the theories he deduced will not in all cases hold to-day in no way reflects upon his ability. In judging his work, as, indeed, judging that of any of his predecessors and contemporaries, one must take into consideration not merely the condition of knowledge at the time, but also the conditions under which they worked.



HENRY DARWIN ROGERS.
State Geologist of Pennsylvania.

One of the most unique figures in early American geology was that of Dr. James G. Percival. This man was born at Kensington, Connecticut, September 15, 1795, and graduated at Yale College in 1815, after which he studied medicine, receiving the degree of M. D. in 1820, and entering upon a troubled and, to his friends, troublesome career, which terminated only with his death in 1856.

J. G. Percival's Survey of Connecticut, 1835–1841.

He wrote poems, became editor of a newspaper, was a proof reader and assistant to Noah Webster in the preparation of his dictionary, and received a Government appointment as surgeon at West Point and afterwards with the recruiting service at Boston. But no form of practical work seemed suited to his taste, and he gave up position after position that he might devote himself to literature.

Peevish, often morbid and misanthropic to the point of insanity, and always complaining, truly such is queer material from which to make a geologist. "Slender of form, of narrow chest and with a peculiar stoop, a large, fine head, dark eyes, and inclined to sharpness of features; a wardrobe consisting of little more than a single plain suit brown or gray—which he wore summer and winter until it became threadbare. He never wore gloves nor blacked his boots." Such is the picture held up to our view by his contemporaries.

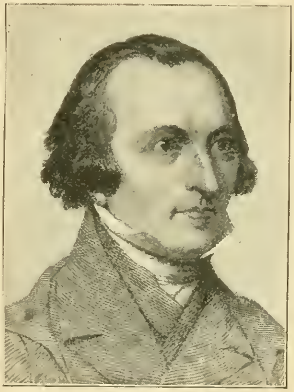


Fig. 25.—James Gates Percival.

A geological and mineralogical survey of Connecticut being organized in 1835, Percival was given charge of the geology and C. U. Shepard the mineralogy. Shepard's report appeared in 1837. It comprised all told some 188 pages, but was not accompanied by a map, sections, nor by figures of any kind.

Percival's report was long delayed, making its appearance finally in 1842. It would seem that the survey, when inaugurated, was expected to be but a superficial one, yet Percival was engaged upon it for five weary and laborious years, each year rendering his researches more minute, until he had collected over eight thousand specimens and made record of dips and bearings still more numerous. The legislators demanded a report, which was not forthcoming, and finally, in 1841, all appropriations were withheld and an abridged report published, much against Percival's wishes. This volume is beyond question one of the least interesting of any issued by any State. A dry mass of lithological details, with little or no discrimination between important and unimportant matters—no theories nor generalities. No one for a moment will question that Percival had been, as he claimed, "laborious and diligent," yet the reader who searches from cover to cover for other facts than lithological characteristics, dip, and strike will search in vain. The fact that the trappean outbursts were not in straight and continuous lines, but curvilinear in form and occupying a series of nearly parallel fissures, was practically the only break in the monotony of detail. He wrote to a friend:

I had twice surveyed the whole State on a regular plan of sections from east to west, reducing the intervals in the last survey to an average distance of 2 miles, thus passing along one side of each of the nearly 5,000 square miles of the State. * * * I had examined all objects of geological interest, particularly the rocks and their included minerals, with minute attention. I had scarcely passed a ledge or point of rock without particular examination.

Peevish and complaining, Percival evidently could not be made to understand why he should not be allowed to go on indefinitely, rendering a report when he himself should be satisfied of its correctness. With such a disposition the average country legislator naturally had no patience, and the abridged report, a volume of 495 pages, with an uncolored map, was finally printed in 1842, as already noted.

Though written by a poet, it is utterly lacking in imagination, and, aside from its dullness, remarkable only from the fact that it is stated to have been written largely from memory. The subjects considered, in the order given, were: First, the rocks or consolidated formations; second, the loose or unconsolidated formations; third, the soils; fourth, economic results, and fifth, the physical geography. The rocks were all classed under three heads: First, the primary; second, the secondary, and third, traps, the distinctions made being on almost purely lithological grounds.

In 1853 Percival was employed by the American Mining Company in exploring the lead mines of Illinois and Wisconsin, and in 1854 was appointed State geologist of Wisconsin, as noted elsewhere. He died in 1856.

In the American Journal of Science for 1836 S. P. Hildreth, later connected with the geological survey of Ohio, published what was, for its time, an important paper relative to the bituminous coal deposits of Ohio and the general geology of the Ohio Valley.

S. P. Hildreth's Work in Ohio, 1836.

Although Hildreth was inclined to indulge in speculations founded upon scanty data, his paper is, nevertheless, important for the numerous sections of the coal strata and as illustrating the condition of knowledge at that day relative to both coal and petroleum.

Hildreth was one of the first to recognize the enormous amount of subaerial erosion that had taken place throughout the region, and that the Ohio River had carved out its own channel. He felt, however, that in times past the precipitation had been much greater than at present, and the abrasion of the surface by rain and torrents much more rapid.

He thought to recognize in the Muskingum Valley Tertiary and Carboniferous rocks with New Red sandstone on the extreme southern border, while on the Clear Fork of the Little Muskingum he noted the occurrence of a white limestone which he erroneously assigned to the Lias.

Considerable attention was given to the "muriatiferous" rocks, and he noted the outcropping of a 5-foot bed of coal in the vicinity of the salt deposit as "evincing apparent design in Him who laid the foundations of the earth in the greater abundance of coal in those places where it would be the most useful," i. e., in the evaporation of brine for making salt. The occurrence of petroleum springs on the Little Kanawha he thus describes:

> By opening and loosening with a spade or sharpened stick, the gravel and sand * * * the oil rises to the surface of the water, with which the trench is partially filled. It is then skimmed off with a tin cup or some other suitable vessel, and put up in barrels for sale or domestic uses. In this way from 50 to 100 barrels are collected in a season, and much more could be gathered if demand required. In the adjacent hills is a thin bed of coal * * * but the source whence this petroleum flows must be deep in the earth, and the material which furnishes, vast in dimensions. The process is one of nature's hidden mysteries, carried on in her secret laboratory, far beyond the reach, and inaccessible to the curiosity of man.

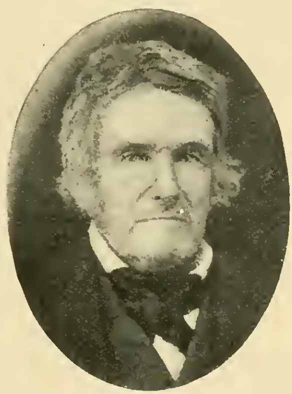


FIG. 26.—Samuel Prescott Hildreth.

The occurrence of gas springs he also noted, and one in the center of an open tract, "given to the public by the liberality of Washington," who "viewed it as an interesting natural phenomenon which no parsimonious individual ought ever to appropriate to his own benefit," is described in some detail and the same reverential spirit. "There appears to be no diminution in the amount of gas from its first discovery to the present time. The same Almighty and liberal hand, which furnished the perennial fountains with water, having also provided this gaseous spring with the means of an exhaustless supply."

Hildreth's supposed discovery of the Liassic age of the white limestone, noted above, was later disputed by John Banister Gibson, chief justice of the supreme court of Pennsylvania, who claimed the credit for himself. Both were, however, in error, as shown by subsequent investigation.

Mather's Geological Survey of Ohio. 1836.

In 1836 there was organized the first geological survey of the State of Ohio, and W. W. Mather appointed chief geologist. The survey lasted two years, seeming to have fallen through on account of local jealousies. Two annual reports were issued, of 134 and 286 pages, respectively, both bearing date of 1838.

Mather's assistants were the S. P. Hildreth, just mentioned, who early resigned on account of ill health; J. P. Kirtland, Dr. John Locke, C. Briggs, jr., J. W. Foster, and Charles Whittlesey, the last named in charge of topographic work. Mather's own work was largely of an economic character, and he showed here as in his later work on the New York survey, a lack of discrimination or ability to judge of the comparative value of the different subjects with which he had to deal.

Hildreth's report must be read with a certain amount of allowance, since his ill health and consequent resignation precluded him from making certain possible modifications of his earlier statements. He described the occurrence of New Red sandstone, Lias, Oolite, etc., overlying the coal, and dwelt to a considerable extent upon the possible value of the buhrstone and also upon the salt springs.

Locke's report, comprising pages 201–286 in the second annual, was by far the most satisfactory, showing a much broader grasp of the general subject than that of any of his associates. He described the rocks below the coal formation as having evidently been deposited in the bed of a deep primitive ocean, though he failed to realize, or at least ignored, the value of the fossil remains in which the rocks abounded, his classification being wholly lithological. As pointed out by Orton, moreover, he failed to correlate the members of the series which he found with those of the same series elsewhere.

He noted the immense amount of drift material, and also the scratched and grooved surface of the underlying rock, describing it as "planished as if by the friction of some heavy body moving over it and marked by parallel grooves." He regarded such as having probably been formed by icebergs floating over the terrace and dragging gravel and bowlders frozen into their lower surface. In this he followed Hitchcock.

Briggs's reports, comprising some seventy pages of the first and second annuals, contained nothing of more than very local interest. A section was given showing the relative position and thickness of the strata in the counties of Wood, Crawford, Athens, Hocking, and Tuscarawas, but no attempt was made to refer them to any particular geological horizon, nor was the value of fossils recognized at all. In fact, there was but the briefest allusion to fossils, excepting as curiosities. This seems the more remarkable, in the case of Locke as well, when we consider that these regions are peculiarly prolific in invertebrate remains and the very important rôle such have since been made to play.

To Foster was assigned the geology of Muskingum County and parts of Licking and Franklin counties. He classified the rocks of the various formations of these regions as Alluvium, Tertiary, Coal Measures, fine-grained sandstone, shale, and Mountain limestone, and noted the presence of remains of a mastodon and a casteroides in the alluvium.

WILLIAM WILLIAMS MATHER.

Geologist of New York State Survey.

Whittlesey's results consisted of, first, a brief pamphlet of some eight pages, relative to the general topography of the State, and second, a report of seventy-one pages, in which he gave geological sections of the rocks from Cleveland to the southeast corner of the Western Reserve, with miscellaneous notes on the order of the strata and on coal, limestone, iron ores, mineral springs, etc.

The general results of the survey may be summed up as follows: The principal formations, as indicated, beginning with the oldest, are first, the great limestone deposit (Silurian and Devonian) which was erroneously regarded as equivalent to the Mountain or Carboniferous limestone of Europe. This was found in Adams County, extending thence to the western portion of the State. It was felt by Locke as not unreasonable to suppose that the particles composing it were once held in aqueous solution and subsequently deposited in tranquil waters along the bottom of the ocean. This may then have been consolidated by subterranean heat. Overlying this is a bed of shales (Upper Devonian) two or three hundred feet in thickness, black, fissile, and with a fetid odor. Next comes Waverly sandstone, the series being thus first named. Fourth, a conglomerate cropping out on the western border of the Coal Measures and varying in thickness from 80 to 100 feet. Fifth, a lower coal series, consisting of alternations of sandstone, shales, limestone, iron ores, and coals, some 300 feet in thickness. Sixth, buhrstone. Seventh, the upper coal series, made up of sandstones, shales, coal, iron ores, and limestones. Eighth, the Tertiary deposits, under which head he included the prairies or barrens in the western part of the State, and the pebble beds and bowlders of primitive rocks so abundant in some parts of the Scioto Valley; and ninth, the recent deposits, including as such those now forming along the river beds. The beds were noted as having generally but a slight dip and irregular undulations. Locke found near the boundary of Ohio and Indiana a summit level and an anticlinal axis from which the strata dipped in opposite directions, eastwardly in Ohio and westwardly in Indiana. This is apparently the first recognition of what has since become known as the Cincinnati Uplift.

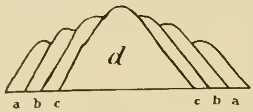
Sketch of Mather.

Mather was educated at West Point, and from 1829 to 1835 was assistant professor of chemistry, mineralogy, and geology in the Military Academy. While there he published (1833) a text-book on geology, a miniature sixteen-mo. volume of some 139 pages, which seems to have been fairly well received at the time and is stated to have passed through several editions.[a] A photographic copy of one of the pages is given

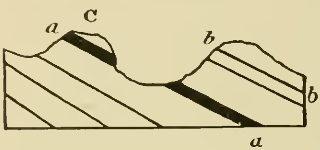
[a] He also published in 1834 a 36-page pamphlet entitled a Sketch of the Geology and Mineralogy of New London and Windham counties, in Connecticut, the same being accompanied by a colored geological map.

below to show the general character of the work and the now seeming crudity of the illustrations.[a]

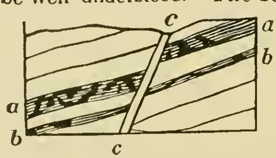
the strata appear to rest against the sides of the mountain masses; *d* being the mountain, and a a, b b, c c, similar strata of rocks.



There is another instance in which the strata may not terminate at their outcrop, but appear again in the opposite hill, as *a a*, but *b b*, by its prolongation, would pass over the hill *C*. Where the strata are nearly horizontal similar strata are almost always found on the opposite sides of a valley, as if they had been formerly continuous, and the valley since formed by some powerful cause.



There is another point in relation to stratification, (and it is also applicable to *veins*, in rocks that are not stratified,) that, from its practical importance in mining, should be well understood. The bed of coal, or vein of ore, appears suddenly to terminate. When this occurs, the bed may be found again, either above or below its original level. At its apparent termination, a fissure, or else a different kind of rock, occurs, generally in the form of a vein, as *c c*. Repeated observation has shown, that if, at the apparent termination, the rock cutting it off inclines towards you, so as to project over your head, the bed of coal, or other mineral, lies at a lower level on the other side of *c c*, as though the mass of strata on one side of the vein had slid down to a lower level. In the figure, *a a* and *b b* repre-



Does the same stratum ever appear on the opposite sides of vallies? When beds of coal terminate suddenly, can they be regained? and how? What has been observed of the positions of the beds of coal, in reference to the sloping of the vein or dyke?

FIG. 27.—Page from Mather's Elements of Geology.

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[a] A copy of this book, in the possession of the present writer, has the following printed indorsement pasted on the inside of the front cover:

[Recommendation of Professor Silliman, of Yale College.]

DEAR SIR: You ask my opinion of the Elements of Geology, for the use of schools, by Wm. W. Mather. I think that it is a judicious, correct, and perspicuous work—containing, in a small compass, a solution of many of the most important facts and theoretical views in geology, and that it is well adapted to the object for which it was written.

Yours, respectfully,

B. SILLIMAN.

Mr. WM. LESTER, Jr.
NEW HAVEN, *June 18, 1834.*

Mather resigned his commission in 1836 and gave up his time wholly to science. He was for a short time professor of chemistry and mineralogy in the University of Louisiana, but in 1836 became connected with the Ohio State survey, and afterward with those of New York and Kentucky, as mentioned elsewhere.

He is described as a large and robust man, with great capacity for physical and mental labor—a man "equable in his disposition and gentle in his manners, considerate of others and just in his judgment of them, modest, but manly and self-reliant and thoroughly versed in the branches of science to which he devoted himself."

Cotting's Work in Georgia, 1836.

With a view of directing the attention of the legislature to the important subject of a geological and agricultural survey of the State of Georgia, the patriotic citizens of Burke and Richmond counties in 1836, at their own individual expense, directed Prof. John R. Cotting—

to make a geological and agricultural survey of their respective counties. To examine all localities of limestone, marls, and all other minerals useful in agriculture and the arts. Also rocks that may be proper for the purpose of architecture, the construction of roads, railways, etc. To examine the water of springs and wells with regard to the salubrity or insalubrity of the same. To analyze the soils on different plantations in the two counties, with a view to their improvement. To illustrate the whole by drawings, diagrams, and a chart of the two counties, and to present a report of the same to his excellency the governor, in order that it may come properly before the two branches of the legislature should he deem the subject of sufficient importance.

In conformity with these instructions Cotting, in the latter part of March, began his survey, which was continued for eight months, the results appearing in the form of a duodecimo volume of 198 pages, unaccompanied by drawings or maps of any kind, since such could not be made within the State and the time assigned for publication would not permit of the original drawings being sent north.

The work was divided into three parts: (1) Topography, (2) economic, and (3) scientific geology. The ideas advanced were naturally largely a reflection of those held by English and European authorities. The formations were divided into Tertiary, Secondary, Transition, and Primitive. Granite was recognized as an igneous rock, but it does not appear that the fact of its deep-seated origin and subsequent exposure by erosion was taken into account.

Many of these rocks [he wrote] occur not only together, forming a group or series, but are ejected in fragments through others and over incumbent strata to the highest series, assuming the appearance of having been once in a fused state. Thus fragments bearing all the features of having been fused or, at least, acted upon by fire or intense heat, occur scattered over the surface or imbedded in the strata of the Tertiary and Diluvial of this district, affording a demonstration that this region of country has been subjected to violent internal forces. The granite or syenite exhibits marks of some great force acting laterally and perpendicularly, which has rent the mass, heaved it up, and projected some of the fragments to a great distance.

It is evident here that he considered the bowlder structure incident to decomposition as original and due to method of extrusion.

Some interesting views regarding volcanic agencies are given in discussing the possible origin of the buhrstone, a chalcedonic rock carrying abundant casts of shells. The material as found occurred "only on the upper part of eminences and the edges of inverted cones." This he seemed to think offered a sufficient demonstration of its igneous origin, and he would account for its uplift on the theory of submarine explosions taking place over a large extent of sea bottom simultaneously. The vesicular character of the buhrstone he likewise regarded as indicative of its volcanic origin. "It is highly probable that the fused mass in that state was spread over the bottom of the then existing ocean and that these vesicles or holes were the effect of water converted into steam by the influence of the heat of the mass." Inasmuch as the fusion of silica without the aid of some other constituent to act as a flux is a phenomenon unknown in nature, such views now strike one as somewhat extraordinary. Nevertheless they were in accord with their time.

Although no use was made of fossils in attempting to ascertain the relative age of the various rocks, he nevertheless recognized the fact that they indicated a sedimentary origin. He wrote:

> Geological investigation has led to the conclusion that there have been a number of deluges at different periods or, rather, that the oceanic waters have swept over the land, continued for an indefinite period, and then retreated several times, leaving their débris behind them. In no other place, perhaps, is the truth of the hypothesis better established than in this region, where fossil remains of different animals characterize different formations, as it is evident that these fossils must have been formed from animals who could not have existed under the earth, but on its surface and at the bottom of the then existing sea.

This well-meant attempt to arouse public interest proved only partially successful. The legislature of the following winter adopted a resolution authorizing the governor to employ a suitable and well qualified person to undertake the work and appropriated $10,000 to carry it on. Doctor Little was thereupon appointed State geologist, but as the legislature of 1840 abolished the office nothing of value was accomplished.

For but the third time in this history we are called upon to step beyond the limits of the United States, and for the second time upon the soil of Nova Scotia, a land still later made famous through the labors of Logan and the elder Dawson. In 1836 there appeared a volume of 272 octavo pages, entitled Remarks on the Geology and Mineralogy of Nova Scotia, by Abraham Gesner. This had been preceded only by Jackson and Alger's work, and was for its time unquestionably a remarkable book. A geological map of the interior of the peninsula accompanied the volume. The southwestern border was colored as occupied by primary

Gesner's Work in Nova Scotia, 1836.

granites, gneiss, and mica-slate, this being succeeded by a wide belt (colored blue) of transition slate, graywacke, and graywacke slate, and this, in its turn, by a broad band of sandstone (colored red) extending up as far as Westmoreland County, New Brunswick. The broad belt of trap rocks along the southwest shore of the Bay of Fundy was colored green. Important beds of iron ore were indicated in the transition slate and of coal in the red sandstone. These districts were described in considerable detail, and attention was called to the fact that the different formations corresponded in direction and general character with those of the United States.

Gesner's ideas regarding the uplifting of strata and the causes thereof were not at all in advance of his time. Thus writing of the position of the slate:

> The strata are variously inclined, and in some cases much twisted and broken; but generally they are so placed as to support the opinion that the primary rocks under their southern side have been uplifted by some violent and sudden movement which has thrown the neighboring slate in its present leaning, and often perpendicular, position.

The iron ore of the South Mountains he regarded as of aqueous origin, such being demonstrated by the presence of the marine fossil shells which it contained. Their presence, however, he was unable to explain.

> From whence came these shells, and by what mighty convulsions and changes in this globe have their inmates been deprived of life and incarcerated in hard, compact, and unyielding rocks? By what momentous and violent catastrophe have they been forced from the bottom of the ocean, where they were evidently at some former period placed, to the height of several hundred feet above the level of the present sea, and even to the tops of the highest mountains?

And further on:

> It is evident that the slate and ore containing the shells already mentioned were once at the bottom of an ancient sea. * * * By some mighty revolution the ground occupied by them has been uplifted and their native submarine possessions converted into slate, and even iron ore.

The fact that some of this iron ore is magnetic was regarded by Jackson and Alger as due to the presence of trap rock. Gesner, however, considered this as not probable, and called attention to the fact that the trap rocks are placed in a situation indicating a date much later than the New Red sandstone upon which they rest.

Notwithstanding the crudity of his notions as to the manner in which the fossil remains had become entombed, Gesner possessed very advanced ideas concerning their value for correlation purposes. This is shown in his discussion of the slate range extending from Yarmouth to the Gut of Canso. The fossils found therein, he felt, had an existence coeval with the original stratification.

They were inhabitants of the same age, enjoyed similar bounties, the same climate, and were companions at a period when the waters of the sea were as warm as those of the present tropical oceans; a fact easily proved by their organization and the beauty and delicacy of their shelly coverings. The corals, coraline sponges, and other vegetable productions of that period, although bearing a striking resemblance to those now flourishing in submarine situations, have nevertheless some peculiar characteristic features, distinguishing them from species of the same classes now inhabiting our shores, although their lineal descendants have long since passed away.

Gesner was an extreme catastrophist, and his ideas concerning the origin of the drift, as well as that of coal, were formulated more or less by the scriptural account of the flood. Discussing the fragments of slate and the masses of quartz rock and granite that were found scattered over the surface of the Red Sandstone, and even entering into its composition at great depth, he argued that their shape demonstrated that they had been transported by the efforts of mighty currents. From this fact he conceived that similar causes had operated upon the surface of the earth at separate and distinct periods of time, one period having produced the ingredients of the newer rocks, which in their turn had been evidently denuded by the rapidity of overwhelming floods. He thought it probable that the first great catastrophe arose when the earth emerged from beneath the waters at its first creation, before which darkness was upon the face of the deep, and that it was not improbable that another geological event may have produced another class of phenomena at that period when the "windows of heaven were opened and the fountains of the great deep broken up."

The giant bowlders, sometimes found on the very hilltops, he recognized as erratics, but could not believe them to be due to flood action. "They have doubtless been thrown upwards," he wrote, "and left cresting the highest ridges, by volcanic explosions that have taken place since the general inundation of our planet." The general phenomena of the drift, however, he regarded as almost certainly the effect "of an overwhelming deluge which at a former period produced those results now so manifest upon the earth. Not only hath the granite sent its heralds abroad, large blocks of trap are also scattered over the soil of Nova Scotia far from their original and former stations."

That coal is of organic origin he recognized, though as to the manner of its accumulation he was somewhat in doubt. He assumed that a part of it at least may have collected at the bottom of the sea, together with successive layers of sand and clay, and that the beds had since been uplifted by volcanic forces. The method of conversion of the organic matter into coal, he thought, might also have been brought about through the intervention of volcanic forces.

In discussing the changes which have taken place on the surface of the earth, he queried if such might not

have been produced between that period when the globe was first created and the Noachian deluge, and might not many of those effects, the causes of which are now almost inexplicable, have been produced at that momentous period when the "windows of heaven were opened, and the fountains of the great deep broken up." * * * In no way can these phenomena be so satisfactorily accounted for and explained as by admitting the brief account of the creation of the world in the first chapter of Genesis; and that there is no necessity for making the world appear older than its date given by Moses.

Again:

The volcanic fires of the earth are gradually becoming extinct. They were evidently far more vehement in former ages than in the present day. Therefore, we have sufficient reasons to believe that from the creation of the world to the deluge great changes must have taken place upon the earth's surface. Who can clearly decide that the flaming sword which forever shut out our first parents from Eden's delightful garden was not a livid torrent of flame issuing from the ground polluted by sin?

Concerning the limestones of the coal formation along the Nepan River, he wrote:

On the surface of the limestone the detritus of the deluge forms a distinct covering; and, according to the opinion of some geologists, should not be considered in any way connected with the changes which have taken place in the strata beneath. But we would remark that although the beds of rounded pebbles and sand clearly demonstrate the effects of a flood, they can have no reference to the great geological catastrophe which ushered in that awful event. The depression of whole continents, the raising of the ocean's level bed, the distortion of strata previously horizontal, the elevation of mountains, and all those violent operations whereby the whole surface of this planet has been rent asunder, might have been the prelude to that overwhelming deluge, while the diluvial débris resulted from the action of torrents after the crust of the globe had been thus broken up.

Gesner was born of German-French ancestry in Cornwallis, Nova Scotia, and was by profession a physician and surgeon. For a long time after obtaining his degree he practiced his profession in the country bordering the shores of

Sketch of Gesner.

Minas Basin, making his visits on horseback, and often returning with saddlebags filled with specimens collected on the way. In 1838, two years after the publication just referred to, he was appointed provincial geologist of New Brunswick, and removed to St. John, where he established the Gesner Museum, afterwards purchased by the Natural History Society of New Brunswick. This was an all-round natural history collection, many of the zoological specimens having been collected by Gesner himself, who was an ardent sportsman.

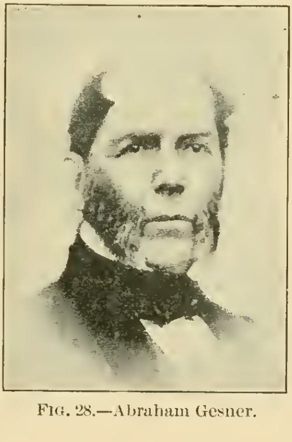


Fig. 28.—Abraham Gesner.

After the somewhat premature closing of the survey in 1846(?), Gesner left St. John and returned to Cornwallis. During his residence here he wrote his works on New Brunswick, with notes for emigrants, and The Industrial Resources of Nova Scotia. Besides his medical practice and the scientific and literary work already mentioned, Gesner engaged in studies in applied science, particularly in electricity and chemistry, and in 1854 took out a patent in the United States for the manufacture of kerosene from coal and other bituminous substances. About this period he resided in Brooklyn, New York, and was connected with the company having works on Newton Creek near Perry Bridge. In 1861 he published a work on coal, petroleum, and other distilled oils. He returned to Halifax in 1863, where he died the following year.

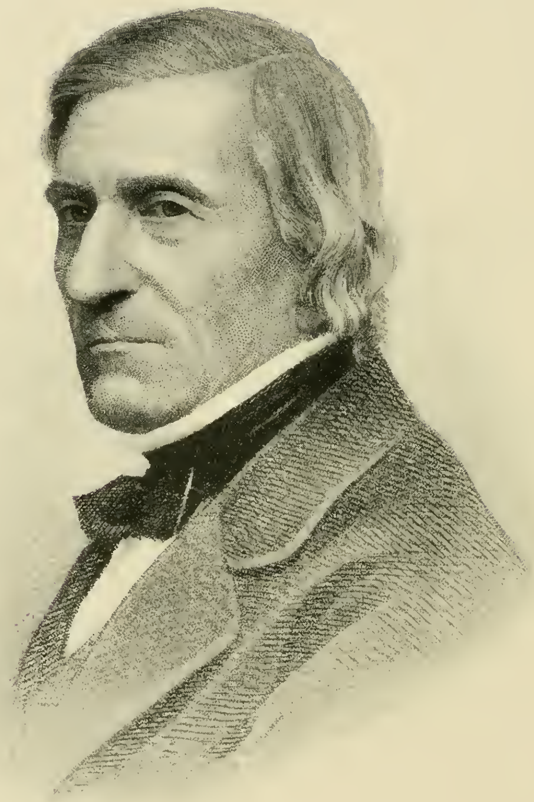
He is represented as a man of medium height, with deep chest and square shoulders, black hair and eyes, and a face showing deep thought and strong intellectual power. He was unquestionably a man of great mental and physical energy. He was noted for his deep piety and remained all his life a firm churchman. It is told of him that, when connected with Guy's Hospital in London, if troubled by any physiological mystery which had become a subject of speculation, he always gave as his ultimate conclusion that "God made it so." This phrase became known as "Gesner's reason" and was so used among the students.

Shepard on Geology of Upper Illinois, 1838.

Although C. U. Shepard's work was mainly mineralogical, he occasionally contributed papers on areal geology. Thus, in the American Journal of Science for 1838, we find an article by him on the geology of upper Illinois. In this he described the extensive Kankakee swamp region south of Chicago, and the old beach lines above the present lake level. He also discussed the possible overflow of the lake in ancient periods to the southward, and dwelt to a considerable extent on the possibility of and the commercial advantages to be derived by uniting the waters of Lake Michigan and the Illinois River, forming thus a connection with the Mississippi.

Fig. 29.—Charles Upham Shepard.

The geology of the region was described as being exceedingly simple and uniform, the great rock formation being the magnesian limestone. He mentioned the occurrence in this of "Orthocera" and large "Pectunculus" and "Terebratula," two species of "Ammonites" and "Caryophyllia," and a "Favosites." The northern boundary of the coal formation he said he could not define with precision through lack of opportunity to explore it in detail. A geological section of the region between Fox River and Spring Creek accompanied the paper.



WILLIAM BARTON ROGERS.

State Geologist of Virginia.

On March 6, 1835, the general assembly of Virginia authorized the appointment of a "suitable person" to make a geological reconnaissance of the State with a view to the general geological features of the territory and to the chemical composition of its soils, rocks, ores, mineral waters, etc. Prof. W. B. Rogers, then professor of natural history, philosophy, and chemistry in William and Mary College, and brother of H. D. Rogers, was selected as the suitable person, entering upon his duties in 1835 and holding the office for seven years. He was assisted from time to time by George W. Boyd, Caleb Briggs, E. A. Aiken, C. B. Hayden, Samuel Lewis, J. B. Rogers, H. D. Rogers, R. E. Rogers, Thomas S. Ridgeway, and M. Wells. The survey continued in existence until the close of 1842, the act of authorization being repealed by the legislature.

Rogers's Work in Virginia, 1835-1841.

No provision was made for the preparation of a final report, although Rogers was ready to undertake the same, and the idea not finally abandoned until as late as 1854. The necessary appropriation was, however, not granted, and the seven brief annual reports submitted are all there is to show for years of careful and patient work under most adverse circumstances. No map and no sections were published at the time. In 1884, after Rogers's death, a reprint of all these reports was made under the editorship of Maj. Jed. Hotchkiss, an engineer, of Staunton, Virginia. They formed an octavo volume of upward of five hundred pages. This was accompanied by a small geological map which Rogers had previously colored for Hotchkiss, and by numerous plates of sections, which are, however, not described in the text.

Under the conditions enumerated above, it is not surprising that the reports contained little of more than local interest, and that the broader aspects of geology were barely touched upon. The region west of the Blue Ridge was described as occupied by fourteen groups of strata, which were designated by numbers, beginning with the lowermost. These all showed so general a conformity in superposition, and so remarkable a correspondence in their mineralogical and physical characters, as to clearly indicate, he felt, the propriety of regarding them all as parts of one great series of strata accumulated over the widely expanded floor of the ancient ocean.

No mention was made of the fossil contents of any of these beds, nor attempts at correlation or determination of their geological age. This seems the more remarkable when one considers the value attached to fossils by Rogers in his work on the Tertiary formations, where the inspection of a single shell, he claimed, would often enable one to pronounce upon the character of the stratum from which it was taken—that is, whether pertaining to the Eocene or Miocene.

The Massanutten Mountains were recognized as one great synclinal tract resting in a trough of slate. It is worthy of note, in view of the

H. D. Rogers-Hitchcock controversy referred to elsewhere (p. 314), that in his report for 1838 Rogers described in considerable detail "the extraordinary phenomenon of inversion" presented throughout the long reach of North Mountains, whereby the entire series from formations II to VIII, inclusive, were found to lie conformably one upon the other, but in a reversed stratigraphical position; that is, the oldest above and the youngest at the bottom. No attempt, however, was made to account for the same.

In the report for 1839 the Tertiary marl south of the James River was described in detail and its Eocene and Miocene subdivisions recognized. In that for 1840 was given a list of the fossils found in the Miocene marls, and attention called to the discovery of a "remarkable stratum varying from 12 to 25 feet in thickness, composed almost entirely of microscopic fossils (Diatoms), and lying between the Eocene and Miocene, but referred to neither." This, the first discovery of its kind in the United States, was referred to as an "infusory stratum."[a] The coarse "middle secondary" conglomerates of Virginia, corresponding to the Potomac marble (Triassic) of Maryland, he regarded as having been deposited by strong currents coming from the southeast which laid down their load in a long, narrow trough extending from southwest to the northeast; such "being deposited in successive layers, commencing at its southeastern margin, would naturally assume the attitude of strata dipping toward the northwest."

When one considers the condition of the country at the time Rogers did his work—the lack of facilities for transportation, the entire lack of maps sufficiently accurate for purposes of plotting, the deep mantle of residuary material that nearly everywhere obscured the more solid rocks, and that there were no railroad cuts or other artificial exposures, such as exist to-day—one can but admire its accuracy. It is not yet too late to express regrets that the parsimony of the legislature should have stood in the way of the preparation of a final report.

W. B. Rogers undoubtedly derived a portion of his enthusiasm for geology from his brother Henry. The first manifestations of this mental trend appeared while professor of natural philosophy and chemistry at William and Mary College in 1833, when he set on foot inquiries relative to the greensand marl of Virginia. His first publication, as given in his biography, however, related to artesian wells and appeared in the Farmer's Register of Richmond (1834–35).

The poverty of his resources in 1835, while hopefully agitating the establishment of a State geological survey for Virginia, can not be better illustrated than by noting the request sent to his brother Henry, in Philadelphia, for the chemicals and apparatus mentioned below to be

[a] In 1843 Tuomey announced the discovery of an infusorial stratum at Petersburg, in Virginia. This he referred to the lower portion of the Miocene.

used in the prosecution of his scientific work. The list comprised 1 platinum capsule, 1 pound of absolute alcohol (French), one-half ounce oxide of ammonia, one-half pound distilled muriatic acid (pure), 1 pound distilled nitric acid, one 4-ounce vial of phosphate of ammonia, 1 foot small platinum wire for blowpipe.

He wrote:

> My alcohol, with all the economy I have used, is almost exhausted. The gill which I had at the opening of the course has been used at least ten times in analysis, and though carefully distilled off in each operation, a portion is, of course, lost.

In August of 1835 Rogers was elected to the chair of natural philosophy in the University of Virginia, at Charlottesville, a position which he gladly accepted, being, undoubtedly, influenced in part at least by the more healthful climate of the latter place.

His first years here were, however, full of trial, owing to the dual nature of his duties—teacher and State geologist—and the lawless character of many of the students. Lacking, as he was, in physical stamina at the beginning, the trials as professor and the lack of appreciation of his work by the State legislature undoubtedly wore upon him severely and had to do with his comparatively early breaking down.

Like other of the broader men of his time, Rogers was an all-round scientist, and wrote not merely on geology, but made observations on the aurora, experiments with reference to binocular visions, and other subjects.

As early as 1846, in connection with his brother Henry, he formulated plans for the Polytechnic School in Boston, which place he felt persuaded was on all accounts the best suited for an institution of this kind. "I long for an atmosphere of more stimulating power," he wrote from Charlottesville, and with these thoughts in mind he resigned his professorship in 1848, but was induced to reconsider and remain for five years longer. On his final removal to Boston in 1853 he continued to take an active part in scientific and educational matters. The year 1859 found him again actively advocating his plan for an institute of technology, the matter being brought forward at this time in connection with the so-called Back Bay lands and their rapidly enhancing value, and in 1861 an act to incorporate the Massachusetts Institute of Technology passed the legislature and was approved by the governor. In 1862, an organization having been perfected, he was elected its first president, an office he continued to hold until forced to resign by ill health in 1870. In 1878, his health having improved, he was again induced to temporarily accept the presidency, holding the position three years, and being succeeded by Gen. F. A. Walker.

His reputation as a geologist rests mainly upon his work as State geologist of Virginia and that on the structure of the Appalachian

Chain in connection with his brother, H. D. Rogers. He was, however, widely known as an educator and orator. To quote from one of his biographers:

> The wide extent of his own studies and researches in mechanics, physics, chemistry, and geology; his truly philosophical spirit, his unfailing courtesy and urbanity, his warm sympathies, his scientific enthusiasm, his commanding and stately presence, his rare gifts of expression, all combined to make him the ideal presiding officer. His introductions were most felicitous; his comments highly suggestive and inspiring; his summing up was always a masterpiece of discriminating and judicious reasoning, while, over all, his rich, tropical eloquence threw a spell as of poesy and romance, for to him the truth was always beautiful, and the most solid and substantial structure of scientific principle stood in his view against a sunset sky, radiant with a light which no painter's pencil ever had the art to fix to canvas.

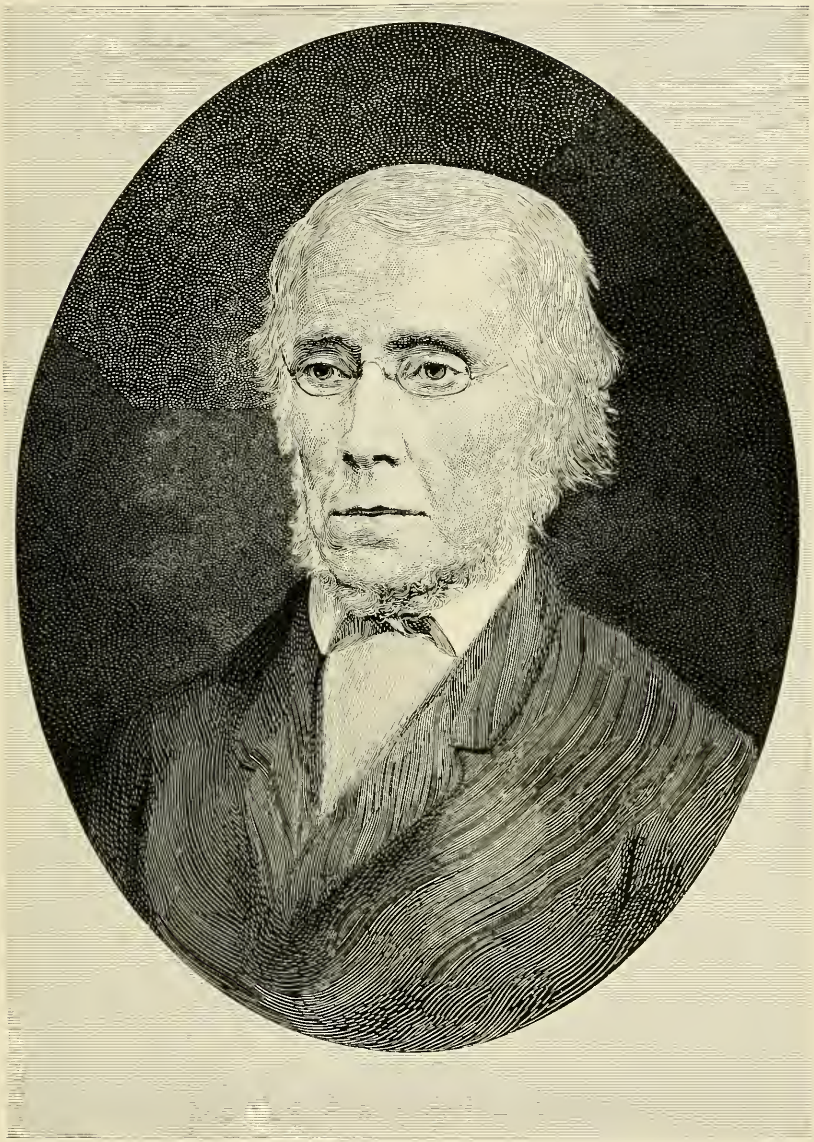
On April 15, 1836, there was authorized by the State assembly a geological and mineralogical survey of New York. This led to an organization which has left a more lasting impression upon American geology than any that has followed or had preceded it. As fate ordained, the locality was one of the most favorable that could have been selected for working out the fundamental principles of stratigraphic geology; moreover, those appointed to do the work proved equal to the occasion. The New York survey gave to American geology a nomenclature largely its own; it demonstrated above everything else the value of fossils for purposes of correlation, and incidentally it brought into prominence one man, James Hall, who was destined to become America's greatest paleontologist.

Geological Survey of New York, 1836.

To secure the greatest amount of individual freedom and to facilitate the work to best advantage, the State was divided into four districts, W. W. Mather being placed in charge of the first, Ebenezer Emmons the second, Timothy A. Conrad the third, and Lardner Vanuxem the fourth. The survey continued in existence for five years, reports being issued annually in the form of assembly documents, the final reports appearing in 1842–43 in the form of quarto volumes, comprising, all told, over 2,000 pages and 82 plates, sections, and maps.

The mineralogical and chemical work of the survey was placed under the charge of Dr. Lewis C. Beck, while Dr. John Torrey was made botanist and Dr. James E. De Kay given charge of the zoological department. At the end of the first season Conrad resigned, to become paleontologist of the survey, and James Hall, who had previously been an assistant to Emmons, was put in charge of the fourth district, while Vanuxem was transferred to the second. As with all the earlier surveys, agriculture and mining were considered subjects of primary importance. The results of the survey can, however, be best considered under the date of issue of the final reports (p. 374).

This same year witnessed also the establishment of a geological survey in the adjoining State of Pennsylvania, of which H. D. Rogers,



TIMOTHY ABBOTT CONRAD.

Paleontologist.

also State geologist of New Jersey, was placed in charge. This survey, as first planned, was expected to continue for a period of at least ten years, but was brought to an abrupt close in 1842, owing to the financial embarrassments of the Commonwealth. Rogers, however, unwilling to relinquish the work in its incomplete form, continued on his own responsibility, and largely at his own expense, for three years longer, and in 1847 deposited in the office of the secretary of the Commonwealth his final report, ready for publication. For reasons to be noted later, the publication of this report was delayed until 1858.

Geological Survey of Pennsylvania, 1836.

During its period of existence the survey issued six annual reports, the first bearing the date of 1836 and the last 1842. These were small octavos, destitute of illustration, with the exception of a few outline sections, and of from 100 to 250 pages each. The results of the work were so completely elaborated in the final reports issued in 1858 that these preliminary publications have been almost completely lost sight of and are of merely historical interest. It is well to note that, owing to the large proportion of foreign population in the State at that date, two editions of the preliminary reports were issued—one in English and one in German. This dual publication, so far as the present writer is aware, was paralleled only in the case of the Ohio survey, under Newberry.

As with the New York survey, the results of Rogers's work can be best summed up in a consideration of the final reports (see p. 489.)

After nearly ten years of agitation, there was passed by both houses of Congress, and approved by the President on May 14, 1836, a bill providing for an exploring expedition to the South Polar regions and the islands and coasts of the Pacific. This expedition, which finally sailed from Norfolk on August 17, 1838, and which, from the name of its commander in chief, has come to be known as the Wilkes Exploring Expedition, had for its immediate object the increase of such knowledge as would be of interest and value to the whaling industry, which had suffered severely through loss of men and vessels in these remote regions. Research along other lines was purely secondary. Fortunately, however, the scientific men of the day were fully alive to the possibilities offered, and, through their influence, an efficient corps of trained observers in various lines was permitted to accompany it. Of these only the geologist, J. D. Dana, who sailed on the *Peacock*, comes within the range of our present work, though incidental reference will be made to J. P. Couthouy, who sailed on the *Vincennes*. Inasmuch, however, as no tangible results from the expedition were made known until after the return of Dana, in 1841, the entire matter may also be dismissed here and taken up again under the latter date.

Wilkes Exploring Expedition, 1836.

In March, 1836, sixteen years after her establishment on a basis of independent statehood, the legislature of Maine authorized the appointment of "some suitable person" to make a geological survey of the State "as soon as circumstances will permit," appropriating the sum of $5,000 to cover expenses.[a] On June 25 a contract was entered into with Dr. C. T. Jackson for the carrying out of the same. Jackson seems to have entered upon his duties promptly and energetically, making his first report, a volume of 116 octavo pages, in December, 1836. This was accompanied by an atlas of 24 plates. His results were apparently satisfactory to the legislature, the appointment being renewed the following year and $3,000 appropriated for expenses. Under this appropriation a second annual report of 168 octavo pages was forthcoming. This in its turn was seemingly satisfactory, for the geologist's salary was increased from $1,000 to $1,500 a year, while the sum appropriated for the carrying on of the work was made discretionary with the governor and council. Under such favoring conditions it is not strange perhaps that the State geologist became effusive and brought his third (and last) report up to 276 pages, with an appendix of 64 pages, containing a catalogue of the collections.

Jackson's Geology of Maine, 1836-39.

These reports, examined in the light of to-day, contain very little which would be considered of geological importance. Jackson seems to have roamed somewhat at random over the State, with little idea of the geological structure as a whole, and to have contented himself with making detailed notes on whatever was immediately at hand, regardless of its possible relationship to other formations at a distance and with an eye particularly to economic questions.

From the finding of marine shells at Lubec in layers of clay now some twenty-six feet above high-water mark, he rightly conjectured that the land had been elevated that amount within a comparatively recent period. He regarded the sandstones now known to be Devonian in the extreme eastern counties as identical with the red Triassic sandstones of Nova Scotia, and seriously discussed the possibility of their containing bituminous coal. The slates of Piscataquis County were classed as transition, and the possibility of their carrying anthracite coal was likewise discussed.

In his third annual report he noted the occurrence of fossil plants in the slates of Waterville and remarked on the discovery as being a strange occurrence, since the rocks belong to the older Transition series.[b]

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[a] The legislature of Massachusetts authorized State cooperation in this survey so far as it related to certain public lands which were the joint property of the two States.

[b] At the second session of the American Association of Geologists in Philadelphia, 1841, Professor O. P. Hubbard exhibited a specimen of this slate and was able to show by the aid of "Murchison's Silurian system" that they were not plant remains but annelid trails, a view which Jackson accepted.

The possibility of the occurrence of beds of coal at Small Point Harbor near Phippsburg was investigated. As a result it was announced that there was no possibility of such being included in rock of the nature there found, and that the coal sometimes thrown up on the beach was presumably from English sources. So early a statement of this nature is interesting in view of borings for coal which have taken place along this coast within a very few years.

Jackson's views on the glacial deposits were naturally crude. The "horsebacks" (ridges of glacial gravel) were regarded as diluvial material transported by a mighty current of water.

It is supposed that this rushing of water over the land took place during the last grand deluge, accounts of which have been handed down by tradition and are preserved in the archives of all people. Although it is commonly supposed that the deluge was intended solely for the punishment of the corrupt antediluvians, it is not improbable that the descendants of Noah reap many advantages from its influence, since the various soils underwent modifications and admixtures which render them better adapted for the wants of man. May not the hand of Benevolence be seen working even amid the waters of the deluge?

It is, perhaps, doubtful if the hard-fisted occupant of many of Maine's rocky farms would be disposed to take so cheerful a view of the matter.

However Jackson's work may impress the reader of to-day, it was considered by a reviewer in the American Journal of Science (XXXII, 1837) as a "model of its kind. It has certainly not been surpassed by any similar effort in this country," and "The present sketch of Maine is a masterly production."

In 1839 the general assembly of Rhode Island appropriated the sum of $2,000 to pay the expenses of a geological and agricultural survey of the State, and Doctor Jackson, fresh from his work in Maine, was placed in charge of this also, making his report the following year. This constituted the first, last, and only survey of Rhode Island carried on under State auspices.

Jackson's Survey of Rhode Island, 1839.

Such a work was naturally productive of little of importance, and no new principles whatever were evolved. Aside from the gathering of a few facts of possible economic value, it resulted only in an extension of knowledge relative to the distribution of certain geologic groups. This, however, was a feature of all the work carried on by Jackson. As further illustrating the condition of geological knowledge, the report is, however, worthy of consideration.

In his introduction he remarked on the attempt on the part of some geologists to abandon the name Transition and to group these rocks with the Secondary, according to the original schemes of Lehman, and felt that a numerical division would doubtless be found preferable to any of the fanciful names proposed for some of its subdivisions. The names Cambrian and Silurian, as proposed in England, he thought, "will never be regarded in this country as appropriate terms for our rocks." He recognized the existence of contact phenomena, and also that the degree of crystallization and general structural features of an igneous rock are dependent upon conditions of cooling, though he regarded pumice as being formed when the fused rock, under little pressure, was brought in contact with water. The possibility of the cellular structure being due to expansion of vapor of water in the lava itself was not recognized. The hornblende rock, so extensively developed in Cumberland, Smithfield, and Johnston, he regarded as of igneous origin, and suggested that its apparent stratiform structure might be due to an admixture of the argillaceous slate through which it was elevated.

The eruptive nature of the Cumberland iron ore was also recognized, though naturally the fact that the rock was an iron-rich peridotite partially altered into serpentine, as later described by Wadsworth, was overlooked.

The origin of the drift was to him still obscure. Concerning the distribution in the form of bowlders of the iron ore to the southward, above mentioned, he wrote:

> There can not remain a doubt that a violent current of water has rushed over the surface of the State since the elevation and consolidation of all the rocks and subsequent to the deposition of the tertiary clay, and that this current came from the north. * * * Upon the surface of solid ledges, wherever they have been recently uncovered of their soil, scratches are seen running north and south and the hard rocks are more or less polished by the currents of water which at the diluvial epoch coursed over their surfaces, carrying along the pebbles and sand which effected this abrasion, leaving striæ, all of which run north and south, deviating a few degrees occasionally with the changes of direction given to the current by obstacles in its way.

He did not accept the theory of drifting icebergs, "nor can we allow that any glaciers could have produced them by their loads of sliding rocks, for in that case they should radiate from the mountains instead of following a uniform course along hillsides and through valleys."

The report was accompanied by six plates of Coal-Measure fossils and a geological map.

Geological work in Delaware at the expense of the State began and ended with the survey by J. C. Booth, a chemist, during 1837–38. Incidentally, it may be remarked that Mr. Booth's career as a geologist was equally prescribed.

Booth's Survey of Delaware, 1837–38.

A unique feature of the act establishing the survey was the requirement that an equal portion of the appropriation should be expended in each county, regardless of existing conditions. The clause was presumably inserted to allay local jealousies, but the absurdity of the same is, nevertheless, so great as to leave no room for comment. In the report, which appeared in the form of an octavo volume of 188 pages in 1841, the geological formations of the State were divided into (1) Primary, (2) Upper Secondary, (3) Tertiary, and (4) Recent. The geographical distribution and lithological character of each was given in detail. The Primary included gneiss, feldspathean rocks (traps), limestone, serpentine, and granite; the Upper Secondary, the Red Clay Formation and the Green Sand Formation. The Tertiary he divided into the northern Tertiary, the southern Tertiary, the yellow-clay formation of Appoquinimink Hundred, and the intermediate clays and sands. The Recent Formations were divided into the lower clays, the upper sands, and the river deposits. Attention was given to the Greensand and to other questions of economic interest.

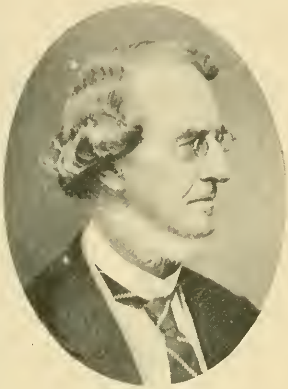


FIG. 30.—James Curtis Booth.

The report as a whole represents the patient attempt of a man unversed in the broader problems of geology who wrote down only what he saw and thought he understood. His remarks on the weathering of rocks are perhaps the most striking. The entire cost of this survey to the State was $3,000, of which sum Booth received $2,000 for his two years' work, the remainder going to defray cost of publication of the report and various incidentals.

In 1837 there was organized the first State geological survey of Indiana, Dr. D. D. Owen, who had served as an assistant on the survey of Tennessee under Gerard Troost, being appointed State geologist. The life of the survey was limited to two years, and two reports were rendered, one of 34 pages, bearing date of 1838, and one of 54 pages, bearing date of 1839.[a]

D. D. Owen's Survey of Indiana, 1837–39.

The essential similarity of the formations of Indiana with those of Ohio was recognized. The lowest lying, oldest rock, called blue limestone,[b] which he regarded as the equivalent of the Lower Silurian limestones of Europe, was described as forming, near the common boundary line between Indiana and Ohio, a kind of backbone which dipped gently in east and west directions, gradually disappearing in both States beneath a series of overlapping strata which, with one exception, have uniform characteristics. Here for the second time (see p. 333) is recognized the presence of the low swell known later as the Cincinnati anticline or uplift, which was subsequently identified by Newberry and Safford as a Middle Silurian emergence. This blue limestone was overlain by another limestone, regarded as the

[a] Reprints of these appeared under date of 1859.

[b] This is the equivalent of the Cincinnatian division of the Lower Silurian of recent writers.

equivalent of the Cliff rock (Niagaran) of Doctor Locke; this, in its turn, by a series of black slates, the equivalent of the Waverly sandstones of Ohio, and this in turn by a series of limestones in part oolitic and the equivalent of the Ohio conglomerate. This last, immediately upon which the coal formation rests at Oil Creek, in Perry County, he considered the uppermost member of a new series, to which he applied the name sub-Carboniferous, "as indicating its position immediately beneath the coal or Carboniferous group of Indiana," and "which merely indicates its position beneath the Carboniferous group without involving any theory."

Immediately overlying this sub-Carboniferous limestone was his bituminous coal formation, the latest and youngest of the series with the exception of the diluvium. He regarded the bituminous coal formation as a part of a great coal field which included nearly the whole of Iowa and Illinois and eight or ten counties in the northwestern part of Kentucky, and recognized the improbability of anthracite coal being found within the limits of the State.

He recognized the importance of fossils in geological correlation and, through the presence of the characteristic forms *pentremites* and *archimedes*, correctly referred the oolitic rock to the sub-Carboniferous, notwithstanding its close lithological resemblance to the Jurassic oolites of England and the European continent.[a]

Sketch of D. D. Owen.

David Dale Owen was a son of Robert Owen, the well-known philanthropist and founder of the communistic societies at New Lanark, Scotland, and New Harmony, Indiana. He first came to America in 1828, but in 1831 returned to Europe, in company with Prof. H. D. Rogers, for the purpose of qualifying himself in chemistry and geology. Returning to America in 1832, he studied medicine at the Ohio Medical College in Cincinnati, from whence he graduated in 1836.

His earliest geological work was done in connection with Dr. Gerard Troost in Tennessee, and his earliest independent work that which has just been mentioned. Subsequently he made surveys under the United States General Land Office, in which work he showed administrative ability of no ordinary kind. Indeed, the organization and carrying out of the plan for a survey of the mineral lands of Iowa, Minnesota, and Wisconsin (in 1839–40) within the short space of time and under the conditions imposed by Congress was a feat of generalship which has never been equalled in American geological history.

[a] There are numerous references in the reports of 1838 and 1839 to sections and a geological map which, however, were apparently never published. In a partial reprint bearing date of 1859 entitled "Continuation of Report of the Geological Reconnaissance of the State of Indiana," made in 1838, where reference is again made to this map, occurs the following footnote: "The original geological map here referred to was deposited in the State library but has not been published."

DAVID DALE OWEN.

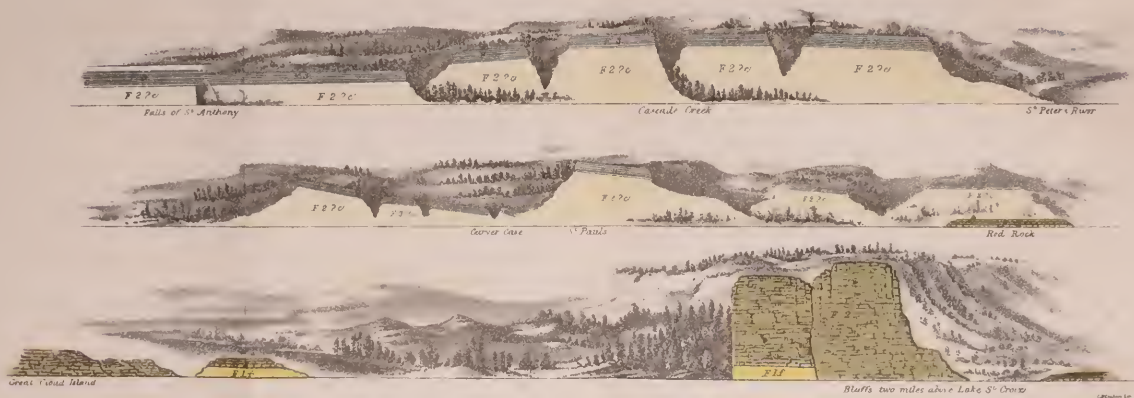
Geologist.

Sec Nº 3

Geological Section on the Mississippi River, from the mouth of Lake Sᵗ Croix little above the falls of Sᵗ Anthony

Showing the relative thickness, and dip of the Shell Limestones (F Nº 3) White Sandstone (F Nº 2 ? c) Lower Magnesian Limestone (F Nº 2) and Lower Sandstone F Nº 1 f

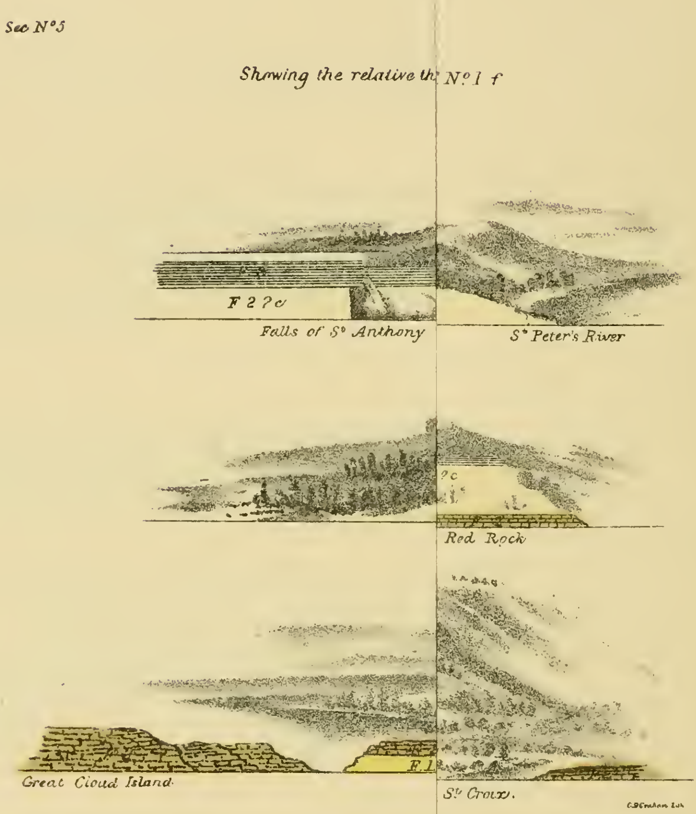
Constructed from observations made by B. F. Shumard & D. D. Owen



ANDREW B. GRAHAM CO. PHOTO-LITHOGRAPHERS, WASHINGTON, D. C.

OWEN'S GEOLOGICAL SECTIONS.

Reduced copy of original in Report of a Geological Reconnaissance of the Chippewa Land District.



GRAHAM CO. PHOTO-LITHOGRAPHERS WASHINGTON D C

His life was one of unceasing activity and furnished one more illustration of the energy, persistence, and virility of the Scotch emigrants and their descendants in America. He is described as a man of amiability, simplicity, and integrity of purpose, and certainly was an artist of no inconsiderable ability, as is exemplified by the sketches in his numerous reports. The geological sections given by him in the report on the Chippewa land district have never been equalled for picturesque effect (see Plate 19).

To properly appreciate much that is to follow, it must be remembered that, beginning with 1807, all Government lands containing ores were reserved from sale and a system of leasing adopted. No leases were, however, issued until 1822, and little mining was done previous to 1826. For a few years, according to Whitney, rents for the mining lands were paid by the operators with comparative regularity, but after 1834, in consequence of the innumerable fraudulent entries of lands as agricultural which should, in reality, have been reserved as mineral, the smelters and miners refused to make any further payments, and the United States officers were entirely unable to enforce the claims of the Government.

D. D. Owen's Surveys of Iowa, Wisconsin, and Illinois, 1839–40.

In consequence of these difficulties a resolution was adopted in the House of Representatives, on the 6th of February, 1839—

> That the President of the United States be requested to cause to be prepared, and presented to the next Congress at an early day, a plan for the sale of the public mineral lands, having reference as well to the amount of revenue to be derived from them and their value as public property as to the equitable claims of individuals upon them; and that he at the same time communicate to Congress all the information in possession of the Treasury Department relative to their location, value, productiveness, and occupancy; and that he cause such further information to be collected and surveys to be made as may be necessary for these purposes.

In accordance with this act Doctor Owen was appointed Government geologist under direction of the General Land Office (James Whitcomb, Commissioner) to make surveys in Iowa, Wisconsin, and northern Illinois. His first report, bearing date of April 2, 1840, was printed to form House Document No. 239, of the First session of the Twenty-sixth Congress.[a] It comprised, all told, 161 printed octavo pages, with 25 plates and maps, including a colored geological map and several colored sections. Fourteen of the plates were from Owen's own drawings. The district explored comprised an area of about 11,000 square miles lying in equal portions on both sides of the Mississippi River, between latitude 41° and 43°, beginning at the north of Rock River and extending thence north upward of 100 miles to the Wisconsin River. (See fig. 45.)

[a] A reprint or second edition of the work was brought out in form of Senate Document No. 407, 28th Congress, 1844.

Doctor Owen's commission reached him at New Harmony, Indiana, on August 17, 1839, and its acceptance demanded that he explore "all the land in the Mineral Point and Galena districts which are situated south of the Wisconsin and north of the Rock rivers, and west of the line dividing ranges 8 and 9 east of the fourth principal meridian; together with all the surveyed lands in the Dubuque district," and complete his work before the approaching winter should set in. Concerning these somewhat remarkable conditions, Owen writes:

After duly weighing the nature of my instructions, estimating the extent of country to be examined, considering the wild, unsettled character of a portion of it, and the scanty accommodations it could afford to a numerous party (which rendered necessary a carefully calculated system of purveyance), and ascertaining that the winter, in that northern region, commonly sets in with severity from the 10th to the middle of November, my first impression was that the duty required of me was impracticable of completion within the given time, even with the liberal permission in regard to force accorded to me in my instructions. But on a more careful review of the means thus placed at my disposal, I finally arrived at the conclusion that by using diligent exertion, assuming much responsibility, and incurring an expense which I was aware the Department might possibly not have anticipated, I might, in strict accordance with my instructions, if favored by the weather and in other respects, succeed in completing the exploration in the required time.

I therefore immediately commenced engaging subagents and assistants and proceeded to St. Louis. There (at my own expense, to be repaid to me out of the per diem of the men employed) I laid in about $3,000 worth of provisions and camp furniture, including tents, which I caused to be made for the accommodation of the whole expedition; and in one month from the day on which I received my commission and instructions in Indiana (to wit, on the 17th of September) I had reached the mouth of Rock River; engaged one hundred and thirty-nine subagents and assistants; instructed my subagents in such elementary principles of geology as were necessary to the performance of the duties required of them; supplied them with simple mineralogical tests, with the application of which they were made acquainted; organized twenty-four working corps, furnished each with skeleton maps of the townships assigned to them for examination, and placed the whole at the points where their labors commenced, all along the southern line of the western half of the territory to be examined. Thence the expedition proceeded northward, each corps being required, on the average, to overrun and examine thirty quarter sections daily, and to report to myself on fixed days at regularly appointed stations; to receive which reports, and to examine the country in person, I crossed the district under examination, in an oblique direction, eleven times in the course of the survey. Where appearances of particular interest presented themselves, I either diverged from my route, in order to bestow upon these a more minute and thorough examination; or, when time did not permit this, I instructed Dr. John Locke, of Cincinnati (formerly of the geological corps of Ohio, and at present professor of chemistry in the medical college of Ohio), whose valuable services I had been fortunate enough to engage on this expedition, to inspect these in my stead.

By the 24th of October the exploration of the Dubuque district was completed, and the special reports of all the townships therein were dispatched to your office and to the office of the register at Dubuque. On the 14th of November the survey of the Mineral Point district was in a similar manner brought to a close, and by the 24th of November our labors finally terminated at Stephenson, in Illinois, the examinations of all the lands comprehended in my instructions having been completed in two months and six days from the date of our actual commencement in the field. Also several thousand specimens—some of rare beauty and interest—were collected, arranged, and labeled.

The immediate result of this examination was to establish the fact "that the district surveyed is one of the richest mineral regions, compared to extent, yet known in the world." The area marked off as including the productive lead region, as shown by his map, lay mainly in Wisconsin, but comprised also a strip of about eight townships on the Iowa side of the river and about ten townships in the northwest corner of Illinois, the ore-bearing strata being limited to a heavy-bedded magnesian limestone which, on account of its characteristic tendency to form perpendicular cliffs when subjected to weathering and erosion, he called the *Cliff limestone*. This, he thought, from its fossil remains, to be the equivalent of the Upper Silurian, and perhaps a part of the Lower Silurian of Murchison. Though sparingly developed in the east, this, according to Owen, "swells in the Wisconsin lead region into the most remarkable, most important, and most bulky member of the group. It becomes, as it were, the Aaron's rod, swallowing up all the rest," and attaining a thickness of upward of 500 feet.[a]

Owen's principal assistants were Dr. John Locke, who reported mainly on the barometrical observations, with particular reference to the measurement of altitudes and the making of geological sections, and a Mr. E. Phillips, who reported on the timber, soil, and productiveness of the region.

Gesner's Work in New Brunswick, 1838–43.

On April 18, 1838, Abraham Gesner, whose work in Nova Scotia we have already referred to (p. 336), was appointed provincial geologist of New Brunswick, a position he continued to hold until 1843, making during this time five brief reports, comprising altogether but 440 pages. A partial geological map was prepared, but never published. A considerable portion of the reports was given up to a discussion of economic matters, particularly the coal beds, the value of which, as noted later, he quite overestimated. The first four reports deal largely with that portion of the province south of the Miramichi, Nashwaak, and St. John's rivers. The fifth and last (1843) describes the country of the upper St. John and that between the headwaters of the Tobique and Ristigouche rivers.

A gradual advance is to be noted, particularly where Gesner in his second report subdivided his graywacke, which he thought comparable

[a] To James Hall's proposition to substitute the name *Niagara* for *Cliff*, Owen objected, claiming that the Niagara, as known in the east, represented only a part of the formation he was describing. In this last he was certainly right, more recent work having shown that his Cliff limestone included also beds belonging to what is now known as the Trenton period of the Lower Silurian.

with Murchison's Silurian, into upper and lower members, of which the upper contained a fossil mollusk which he identified as a terebratulite, and which Dr. G. F. Matthew[a] thinks to have been probably a somewhat poorly preserved *Orthis billingsi*. He also reported the finding of remains of conifers, calamites, and a *cactus* (?), the last being regarded by Matthew as some form imitative of a stigmaria. Though the full significance of these fossil remains was not appreciated by Gesner, yet he must be regarded as a pioneer in making known the flora of both the Cambrian and Carboniferous beds in New Brunswick.

In his fourth report he classed this graywacke with Sedgwick's Cambrian. About this time (1842) he seems to have become acquainted with Agassiz's glacial theories and referred to the expressed opinions of Lyell and Buckland with reference thereto, but thought that "the general occurrence of diluvial grooves and scratches upon the surfaces of the rocks * * * can not in general be explained unless by admitting that a great current of water has passed over the country from the north toward the south," though "it appears that ancient glaciers have had a powerful influence in the accumulation of those parallel mounds of erratic sand and gravel observed in different parts of these provinces, and likewise they may have been the means whereby bowlders of granite and other rocks have been scattered over the country."

In this, his fifth report, he gave a general description of the coal fields of the province, which he estimated as embracing an area of 8,700 square miles, or nearly one-third the entire area of New Brunswick, making it one of the largest in the world. Through the influence of these reports a great deal of interest was excited in the public mind concerning the mineral wealth of the province. A large number of mining adventures were undertaken with the expectation of immediate and favorable returns. Few of these were, however, successful, and the reaction in public feeling tended to throw discredit on Gesner's work and probably was influential in terminating his engagement, the survey being brought to an abrupt conclusion in 1843.

The problem of the Tertiary deposits of the southern Atlantic States, which up to date had been touched upon in a scientific manner only by Finch, Morton, Vanuxem, and Lea, was again, in 1839, taken up by T. A. Conrad. In the journal of the Philadelphia Academy of Sciences for this year Conrad described the Tertiary of Maryland as occupying all the tract south of an irregular line running from the vicinity of Baltimore to Washington, the Potomac being the western and the Chesapeake the eastern boundary. The deposit in the vicinity of Fort

Conrad's Work on the Tertiary, 1839.

[a] Bulletin 15, Natural History Society of New Brunswick, 1897.

Washington on the Potomac, he suggested, was probably contemporaneous with the London clay, i. e. Eocene.

The cause of the change in the character of animal life between rocks belonging to the different animal horizons, was regarded by Conrad as due to climatic changes. "Periodical refrigeration alone can explain the sudden extinction of whole races of animals and vegetables."

It is well to note that in his Geological Report for the State of New York, Conrad recognized the fact that in the earlier eras of our planet the temperature was uniform and the seas comparatively shallow. Hence, he thought, in the older rocks we should expect to find organic remains belonging to one group of species over the whole globe. Deep erosion and greater variation of temperature had caused more uncertainty in the Upper Tertiary formations.

In connection with Conrad's work, it may not be out of place to note that Prof. J. L. Riddell this same year described the surface geology of Trinity County, Texas, and, basing his determinations mainly on the beds of lignite there found, put down the prevailing sandstone as Tertiary.

Incidentally, also, it may be noted that during 1840 Mr. James T. Hodge made a trip through the eastern portion of the southern Atlantic States and made extensive collections of fossils, which were turned over to Conrad for identification. Hodge's notes, as published in the Transactions of the Association of American Geologists, contain little of geological value, but the list of fossils comprised some 134 species, of which 32 were then new to science. All were of Tertiary age.

Conrad was born in Philadelphia in 1803, and from early youth showed a decided taste for natural-history studies, though for a time following the calling of his father—that of a publisher and printer.

Sketch of Conrad.

The work noted on page 306 was his second of geological importance, and was preceded also in 1831 by a paper on American marine conchology. Of his subsequent writings on conchology, paleontology, or general geology upward of twenty related to the Tertiary, and it is upon these that his fame as a geologist chiefly rests, though in addition he described the fossils collected by the Wilkes exploring expedition, by Lieutenant Lynch's expedition to the Dead Sea, by the Mexican boundary survey under Lieutenant Emery, and was first geologist and then paleontologist to the New York State survey.

Personally Conrad was peculiar.

He wrote his letters and labels frequently on all sorts of scraps of paper, generally without date or location. He was naturally careless or unmethodical, and his citations of other authors' works can not be safely trusted without verification, and are usually incomplete. He had a very poor memory, and on several occasions has redescribed his own species. This defect increased with age, and, while no question of willful misstatement need arise, made it impossible to place implicit confidence in his own recollections of such matters as dates of publication. (Dall.)

He himself says, in a characteristic letter to F. B. Meek, written July, 1863:

I go on Monday to help H. ferret out my skulking species of paleozoic shells. May the recording angel help me. God and I knew them once, and the Almighty may know still. A man's memory is no part of his soul.

Conrad was bitterly opposed to the doctrine of evolution, and predicted that Darwin's wild speculations would soon be forgotten. Every geological age came, according to him, to a complete close, and the life of the succeeding one was a wholly new creation. His feeling on this subject is well shown in a letter, also to Meek, dated February, 1869, where he says:

I sent you to-day a copy of my paper in Kerr's geological report. I perceive by Cope, Martin, and Hayden's researches that they have not found that phantom of the imagination, a formation between chalk and Eocene. The world has been so thoroughly harried by despairing development philosophers with so little result that they may as well say the "game is up," and not speculate on lost formations lying at the bottom of the ocean, a desperate expedient to save genetic succession. It is strange that geologists can not recognize an Azoic era after the chalk. I consider, in the light of paleontology, the advent of one only form of life in the beginning to be absurd. The history of Lingula ought to teach us the permanence of certain forms of life from the beginning, while thousands of others were created and died out.

Poor in health, given to melancholy and low spirits, he furnished to American geological history that which has a counterpart only in Percival, and like Percival, it may be added, he was sometimes given to rhyming, though unlike Percival, he was slovenly and careless in his work to a point beyond endurance.

His melancholy increased with age, and frequent ill health caused him at times to lose interest in every undertaking.

A period of moping would usually end in his writing some verses which nobody would praise, and this seemed sufficiently to nettle him, to rouse him thoroughly, and he would become again enthusiastic in the matter of shells and fossils.

It was presumably during one of these moping periods that he wrote again to Meek under date of October 24, 1864, as follows:

I am troubled with the cui bono malady, and frequently wish to be under the "clods of the valley." The idea of suicide haunts me continually, and I wish to get to work to banish the horrors, but whatever side I look at work it brings expenses I think I would regret. Singular inconsistencies of man. I don't expect to live much longer, yet shrink from expenses, but such is the hard mental twist that early poverty gives the mind. My blues have been considerably increased by the death of Doctor Moore,[a] who I loved more than most other men, and by the death of my nearest and dearest sister with whom I lived in Trenton. Now I must plunge into the marl beds to keep up a little time longer and hope to finish the Miocene figures before I go where no dreams of new discoveries will haunt me. Excuse this egotism; it is the last of it; but you now see why I do so little. Only one thing remains. I don't suppose you feel the want of a home, but I have felt it all my life, and the dreams of an Egeria have overtopped the dreams of science, so

[a] Dr. W. D. Moore, of the University of Mississippi.

that in the midst of geological pursuits a horrid vacancy has yawned in my heart, and a grinning devil laughed over a drawer of fossil shells. A small Hamlet in science, I grow old and reform not.

Conrad's Ideas of the Drift, 1839.

Conrad, though primarily a paleontologist, was sometimes drawn out of his chosen field by phenomena too obvious to be overlooked, and concerning the nature of which little was actually known, even by the best authorities. The occurrence of enormous bowlders in the drift and resting often upon unconsolidated sand and gravel, naturally called for an explanation. That such could not have been brought into their present position through floods was to him obvious, neither could they have been floated by ice floes from the north during a period of terrestrial depression.

He assumed, rather, that the country, previous to what is now known as the glacial epoch, was covered with enormous lakes, and that a change in climate ensued, causing them to become frozen and converted into immense glaciers. At the same time, elevations and depressions of the earth's surface were in progress, giving various degrees of inclination to the frozen surfaces of the lakes, down which bowlders, sand, and gravel would be impelled to great distances from the points of their origin. The impelling force might, in some cases, be gravity alone; but during the close of the epoch, when the temperature had risen, vast landslides—avalanches of mud filled with detritus—would be propelled for many miles over these frozen lakes, and when the ice disappeared the same would be deposited in the form of a promiscuous aggregate of sand, gravel, pebbles, and bowlders. The polished and scratched surface of the rocks in western New York he ascribed to the action of sand and pebbles, which were carried by moving bodies of ice, that is, apparently, to local glaciation.

George E. Hayes's Views, 1839.

The year 1839 seems to have been one of remarkable activity among American geologists. Moreover, the various publications began to show a greater variation in individual opinion and a disposition on the part of many to judge for themselves rather than follow too implicitly the opinions of others. Many of the ideas put forward were naturally crude (How could they be otherwise?), but furnish us with a very good insight into the gradual evolution of ideas upon a great variety of subjects.

George E. Hayes wrote upon the geology and topography of western New York and incidentally put forth several theoretical ideas worthy of mention, even though ill-founded. He took occasion to deplore the common custom of invoking the assistance of the Noachian deluge to account for such results as erosion and the distribution of the drift. He felt that "the condition of a continent gradually elevated from the ocean, whether by volcanic action or by the expansive force of crystallization, or by any other cause whatever, would be such as to account for all the geological phenomena hitherto attributed to the mechanical action of water." The formation of such terraces as Hitchcock had described in the valley of the Connecticut he thought might be due to the action of waves and tides. He regarded it as idle to suppose that existing streams have carved out their own channels, and ridiculed the idea that the falls of Niagara were once at Lewiston, seven miles below their present position, as had been contended by the English geologist, Bakewell.

He also decried all attempts at estimating the age of the falls or the time before they would so far cut back as to drain Lake Erie. It was his idea that the channel below the falls was cut while the rocks were being slowly raised above the level of the great inland sea and forming a limestone ridge or reef across which, at its lowest points, strong currents would alternately sweep during the ebb and flow of the tides. As the elevation progressed the currents would become more and more confined to the weakest and lowest points in the barrier, until in course of time the whole force of the conflicting currents would be concentrated at one point. "The power of the waves and the influx of the tide operating from below would be applied to the best possible advantage in tearing up the strata which most impeded their course, while the current, combined with the receding tide, would carry off the fragments. In this manner the valley of the Niagara was doubtless formed." (See Hall's views, p. 384.)

The lake beds of the region he imagined to have been formed by the unequal erosion along the edges of uplifted strata, Lake Erie lying at the junction of shale and limestone. Before this limestone had become sufficiently elevated to shut out the sea from the basin now occupied by the lakes he conceived a strong current to have set in through the Gulf of St. Lawrence, finding its way through the valleys of the Mohawk and Hudson, and dropping on its course the large quantity of bowlders foreign to the localities now so plentifully distributed over the surface.

As early as 1823 Governor Woodbury, in his message to the State legislature of New Hampshire, had recommended an agricultural survey, having particularly in mind chemical investigations of the various kinds of soils. It was not, however, until 1839 that, under the earnest solicitation of Governor Page, a geological and mineralogical survey was organized, and Dr. C. T. Jackson placed at its head. This survey continued for three years, receiving annual appropriations of $3,000 to cover all expenses. The final report appeared in the form of an octavo volume of 375 pages, with two plates of colored sections and an uncolored map of the State on which the various formations, or, rather, rock types, were indicated by numbers. The localities of useful minerals, peats, etc., were also indicated, as were the dip and strike of the more

Jackson's Survey of New Hampshire, 1839–40.

important rocks. J. D. Whitney served as assistant in the laboratory of the survey.

As with other of Jackson's reports, this work contained scarcely anything of a theoretic or advanced nature, although he did suggest that the apparent dipping of the Vermont marble beds under the Green Mountains might be due to "a folding or doubling back of the strata, which may curve around and pass down toward the shores of Lake Champlain, where the same strata may be composed of marine shells." He noted also that the secondary rocks must at some time have been horizontal and formed a continuous deposit extending entirely across the region now occupied by the White Mountains. If, however, the secondary strata were to be restored to their original horizontal position, he found an insufficiency of materials to cover the gap left by the removal of the primary rocks composing these mountains. This he would ascribe to the breaking up of the secondary rocks at this point through the sudden elevation of the primaries and a more or less altering of the same by heat.

It was Jackson's idea, as set forth in this report, that highly inclined stratified rocks could have been made to assume that position only by some distorting cause other than aqueous action. This cause he conceived to be "a deep-seated power residing in the interior of the crust of the globe," the power itself being furnished by the "great caldron of molten rocks and pent up gasès and steam, there being no more difficulty in our conceiving of the adequacy of this force than in the prodigious power of steam in moving the enormous engines" daily seen in operation. He conceived that a better idea of this power might be gained if one "look to the dimensions of the earth's great boiler, and consider the comparative thinness of its sides." Volcanoes he devoutly referred to as safety valves which prevented a general upbursting of volcanic fires, and "hold all in the most perfect order, and preserve the earth in safety."

His views regarding the glacial drift would seem to have undergone no appreciable change since 1839, although perhaps somewhat differently expressed in the later reports. He wrote of this drift as due to the "ocean waters and seas of ice from the polar regions having been hurled with violence over the surface of the northern hemisphere during a period of shallow subsidence." The drifting of bowlder-laden icebergs would account for the glacial striæ, but the glacial theory of Agassiz he looked upon as quite insufficient and absurd. It is to be noted, however, that his only conception of glaciers was that of mountain glaciers of the Swiss type, the onetime presence of which was disproved by the nonradiating character of the drift and striæ. This glacial flood to which he now appealed, however, was not regarded as contemporaneous with the Noachian deluge, but as having occurred before the advent of man.

He recognized the plant origin of the coal beds, considering them as products of growth in low, moist, and warm bogs, which were at no great height above sea level, and which were frequently subjected to slow and gradual submergence and reelevation, in this following the other authorities of the day.

In 1837 there was organized a State geological survey of Michigan, the sum of $3,000 being appropriated for the carrying out of the work the first year, the amount being increased to $6,000, $8,000, and $12,000, respectively, for each of the three succeeding years, which limited the life of the organization.

Houghton's Work in Michigan, 1837-41.

Douglass Houghton, then not 30 years of age, was made State geologist, and during his term of office issued five annual reports, the last bearing date of 1842. His chief assistants were Bela Hubbard and C. C. Douglas. During the winter of 1837-38 the survey was reorganized with particular reference to provisions for zoological, botanical, and topographical departments, and additional assistants were appointed to take charge of these branches of the work.

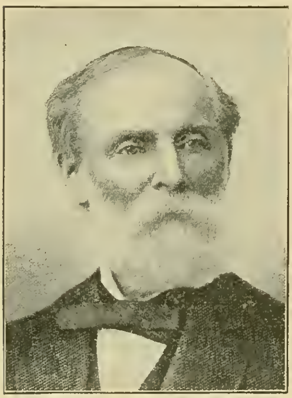


Fig. 31.—Bela Hubbard.

In his first annual report, a document of 37 pages, Houghton noted the geological features of the Lower Peninsula, classifying the formations under the heads of upper sand rock, gray limestone, and lower sandstone or gray wacke group, lying for the most part in nearly horizontal positions. The sandstones of the Upper Peninsula were regarded as belonging to the Carboniferous series.[a]

In his second annual report he detailed the topographical and general character of the northern portion of the peninsula, with special remarks upon the clays, marls, and gypsums. He devoted considerable attention to a consideration of the change of elevation in the waters of the Great Lakes, which were then at a higher point than had been known for many years. Many rather startling and mysterious reports had been previously circulated regarding the abrupt change in the level of the water of the lakes, and hence Houghton's report at this time was of particular significance. His conclusions were to the effect that the entire series of changes were due to periods of increased rainfall.

A special report on the State salt springs was also submitted at about this time. In this Houghton announced that he had visited the salines of Pennsylvania, Virginia, and Ohio with the view of acquiring information to guide his procedure, and had commenced the boring of two wells—one on the Tittabawassee, near the mouth of Salt River, and

[a] Now regarded as Cambrian.

the other at Grand River, a few miles west of Grand Rapids. Both wells, it may be stated, have proved failures, owing to the weakness of the brine.

The third annual report, of 111 pages, contained a description of the topography and geology of the portion of the Upper Peninsula bordering on Lakes Michigan and Huron, together with notices of the coal, iron, stone, and bog ores of the southern peninsula. The rocks of the Upper Peninsula were classified as primary and sedimentary, the latter being subdivided into a lower lime rock and shales and upper lime rocks.

The fourth annual report, 1841, was given up largely to articles by Doctor Houghton on the topography, geology, and mineralogy of the country bordering Lake Superior. This contained also a description of the mineral veins of the trap and conglomerate. Although not so stated here, it may be well to remark that Houghton regarded the copper-bearing veins of the Lake Superior region as fissure veins filled from below by the metal in a state of vapor or of compounds having their origin from copper in the native form.

The fifth annual report was limited to but six pages, owing to the fact that the appropriations by the legislature were curtailed, the country suffering under pressure of a financial crisis. Houghton was not, however, content to drop the work, and in 1844, in connection with W. A. Burt, devised a plan for connecting the linear surveys of the public lands of the United States with the geological and mineralogical survey of the country. This plan was fully set forth in a paper prepared and read by him before the Association of American Geologists at Washington in that year. Under the recommendation of the General Land Office Congress appropriated funds for the purpose, and Doctor Houghton was appointed to undertake the work. According to the plan thus agreed upon Mr. Burt was to take charge of running the township lines of the Upper Peninsula, the subdivisions to be made by deputy surveyors, and Doctor Houghton was to have the directorship of the entire work. The rocks crossed by lines were to be examined, and observations made as to the general geological and topographical features of the country. The system had been fairly organized and the field work of one season nearly completed when, on the 13th of October, 1845, Doctor Houghton met his death by drowning during a snowstorm, while making his way in an open sailboat along the west shore of Lake Superior.

Sketch of Houghton.

Houghton graduated in 1828 at what was then America's chief training school for geologists, the Rensselaer Polytechnic Institute, and was almost immediately appointed assistant to Professor Eaton. In 1830, having but just attained his majority, he delivered a course of lectures at Detroit on chemistry, botany, and geology, an example no man of several times his age would care to follow to-day unless quite regardless of his reputation. But such was the condition of knowledge at that time. In 1831 he entered upon the practice of medicine, and soon after received the appointment of surgeon and botanist to the expedition under Schoolcraft for the discovery of the sources of the Mississippi. His public career as a scientific man began, therefore, with that date.

Houghton is described by his biographer[a] as a man of rather small stature, with hands and feet small and delicately formed; head large and well developed; with blue eyes, well sheltered underneath massive brows, and showing upon his ears, nostrils, and mouth scars from an accidental explosion of powder, which took place during some of his boyish experiments. In early life he had suffered severely from a hip disease which had left one leg a little short, though not sufficiently so to cause him to limp. His temperament was warm and nervous; his movements quick and earnest. Young, ardent, and generous to a fault, he seems to have made friends wherever he went, and soon became the most prominent and popular man in the State.

> Everywhere his ability and energy were acknowledged. No name throughout the distant and rural districts was so often uttered. His daring, his generous acts, his good humor, his racy stories were repeated everywhere. * * * Every man seemed to feel a pride in the growing celebrity of Houghton, and the familiar epithets "The little doctor," "Our Doctor Houghton," "The boy geologist of Michigan," became common throughout the State.

[a] Alvah Bradish, Memoir of Douglass Houghton, Detroit, 1889.

CHAPTER IV.

THE ERA OF STATE SURVEYS, SECOND DECADE, 1840-1849.

The fever for State surveys, so prevalent during the last decade, would seem to have very quickly subsided, since during the period now under consideration such were established only in Alabama, South Carolina, and Vermont. Governmental surveys were also few, being limited to those by D. D. Owen in the Chippewa land district, and Jackson, Foster, and Whitney in the Lake Superior region.

The cause of this sudden cessation is not quite apparent. Nine of the twenty-six States forming the Union at the beginning of the decade had, so to speak, escaped the contagion, and only the three above mentioned succumbed during the period, leaving Arkansas, Georgia, Illinois, Kentucky, Louisiana, Mississippi, and Missouri still unprovided for. It is possible, and perhaps probable, that the period of great financial depression beginning in 1836 may have had something to do with it, but as nine of the sixteen inaugurated during the decade 1830–1840 were established either during 1836 or the three years immediately following, this is perhaps open to question. An important factor may have been the lack of geologists to agitate the subject and carry on the work, nearly every man of prominence and experience being engaged in surveys and organizations already under way. The period was, nevertheless, one of importance, one of manifest results rather than of organization and preparation.

The single event of greatest consequence during the decade was the appearance of the four quarto volumes constituting the final reports of Mather, Emmons, Hall, and Vanuxem of the New York survey, an event which would, however, have been paralleled by the reports of Rogers in Pennsylvania but for the dilatoriness of the State authorities. The volume of literature was naturally greater than at any previous period, since it included many of the reports of organizations of the previous decade, as those of Percival in Connecticut (1842), Booth in Delaware (1841), Jackson in New Hampshire (1844) and Rhode Island (1840), and Rogers in New Jersey (1840). The establishment of a geological survey of Canada in 1841, the coming of Lyell to America in the same year, the publication of his "Travels" in 1844, and the coming of Agassiz in 1846 should also be mentioned. The most noted of the participants in the events of the decade, as will be seen, were H. D. Rogers, then in full vigor; Edward Hitchcock, mature and conservative; D. D. Owen, by all means the leader in reconnaissance work, and W. W. Mather. James Hall was rapidly forging to the front among paleontologists, while J. D. Dana, in the full flush of early manhood and fresh from the experiences of the Wilkes expedition, began the important series of papers dealing with the grander problems of earth history which soon placed him foremost in the ranks of American geologists and, indeed, among the geologists of the world.

Among the names which were to appear prominently in the decade will be found those of E. T. Cox, Ebenezer Emmons, J. P. Lesley, F. B. Meek, B. F. Shumard, Michael Tuomey, and J. D. Whitney.

Geology, at the opening of the decade, had found a place in the curricula of the leading colleges of the land, as at Bowdoin, in Maine; Amherst and Williams, in Massachusetts; Yale, in Connecticut; the Rensselaer Institute, in New York; the University of Virginia, at Charlottesville; the University of North Carolina, at Chapel Hill, and the College of South Carolina, at Columbia.

The Smithsonian Institution came into existence also during this period. The National Institute for the Promotion of Science and the Society of American Naturalists and Geologists were formed at the very beginning of the decade, the last named to be in 1847 merged into the American Association for the Advancement of Science. The retrospect was pleasing, the prospect encouraging.

Agassiz's Glacial Theory, 1840.

In 1840 an immense stride in the study of the drift deposits was made through the publication of Louis Agassiz's Études sur les Glaciers, a work comprising the results of his own study and observations combined with those of Jan de Charpentier, E. T. Venetz, and F. G. Hugi. The work was published in both French and German and brought to a focus, as it were, the scattered rays with which the obscure path of the glacial geologist had been heretofore spasmodically illuminated. But libraries in America were few and far between, the workers were poor, and many remained long in ignorance of the existence of the treatise or gained but a partial and imperfect idea of its contents through hearsay or brief reviews in periodicals.

The prevalent ideas on the subject of the drift have been from time to time given in these pages. It was Agassiz's idea, based upon observations in the Alps and the Juras, and what was known regarding existing conditions in northern Siberia, that at a period geologically very recent the entire hemisphere north of the thirty-fifth and thirty-sixth parallels had been covered by a sheet of ice possessing all the characteristics of existing glaciers in the Swiss Alps. Through this agency he would account for the loose beds of sand and gravel, the bowlder clays, erratics, and all the numerous phenomena within the region described which had heretofore been variously ascribed to the Noachian deluge, the bursting of dams, the sudden melting of a polar ice cap, or even to cometary collisions with the earth.

Agassiz's ideas were favorably received by the majority of workers in Europe and Great Britain, though there was naturally a highly commendable feeling of caution against their too hasty acceptation. As a reviewer in the American Journal of Science has put it:

> These very original and ingenious speculations of Professor Agassiz must be held for the present to be under trial. They have been deduced from the limited number of facts observed by himself and others and skillfully generalized; but they can not be considered as fully established until they have been brought to the test of observation in different parts of the world and under a great variety of circumstances.

The effect of the publication was, however, soon apparent in American literature. Thus, in 1839 James Hall, then a young man of 28 and just coming into prominence in connection with the geological survey of New York, had, with all the confidence of youth, written upon the glacial deposits as they had come under his observation. Such he regarded as due to water action, but to the action of opposite and conflicting, rather than single, uniform currents. The great extent of the deposits and the evidence of long-continued wear shown by their materials proved to him that the force which produced them was not violent and sudden, but continued for an indefinite period.

Four years later (1843) Prof. Charles Dewey, writing on the striæ and furrows on the polished rocks of western New York, argued that, while the bowlders of the drift indicated that a mighty current had swept from north to south, the polishing and grooving might be due to glaciers as described by Agassiz.

> Glaciers or icebergs and the strong current of waters—a union of the two powerful causes—probably offers the least objectionable solution of those wonderful changes.

Though disposed thus to accept in part Agassiz's conclusions, Dewey yet failed to realize their full possibilities. He could not conceive how it was possible for a glacier to transport sandstone bowlders from the shore of Lake Ontario to the higher level of the hills to the southward. Bowlders of graywacke removed from the hills in the adjoining part of the State of New York and scattered throughout the Housatonic Valley furnished a like difficulty, since between the place of origin and that of deposit lay the Taconic range of mountains. "If," he wrote, "the bowlders were once lodged on the glacier, the ice and bowlders must have been transported by a flood to waters over the Taconic Mountains." The Richmond bowlder train, concerning which we shall have something to say later, was likewise a source of difficulty in his acceptation of Agassiz's theory.

At the April, 1841, meeting of the Society of American Geologists and Naturalists Mr. R. C. Taylor exhibited and described in detail a model of the western part of the southern coal field of Pennsylvania. This he stated to be the first model constructed in the United States.

Such being the case, it is worthy of remark that he regarded the then customary (and to some extent still prevailing) habit of exaggerating the vertical relief as "a hideous burlesque upon the actual aspect of the district represented or, rather, misrepresented," and that he had himself "for some time ceased to make any such difference between the horizontal and vertical scale." Taylor, it should be noted, was particularly active during the period 1831 to 1839, his papers relating almost wholly to economic problems and appearing largely in the Transactions of the Geological Society of Pennsylvania. His most pretentious publication was that entitled Statistics of Coal, a volume of 754 pages relating to the coal fields of the world, published in 1848.

R. C. Taylor and the First Geological Model, 1841.

Troost's sixth annual report as State geologist of Tennessee, a pamphlet of 48 pages, was made in October, 1841; his seventh, of 45 pages, in 1843; the eighth, of but 20 pages, in 1845; and the ninth and last in 1848. During the interval between his fifth and sixth reports he had become acquainted with the work of Sedgwick and Murchison in England, and the result is a slight modification of his views regarding the rocks of Tennessee. He now announced the conclusion that those rocks west of the line which separated Tennessee from the State of North Carolina, and previously classified by him as transition under the names of graywacke, etc., belong to Sedgwick's Cambrian system. The range known by the name of Bays Mountains, which extends into Tennessee for about 100 miles in a northeast and southwest direction, he believed to terminate this system toward the west. A few pages farther on he, however, thrust a doubt on this determination by writing:

Troost's Work in Tennessee, 1841.

> I consider * * * that Bays Mountain forms the upper part of the Cambrian system or that it perhaps belongs to the Old Red Sandstone; that thence toward the north of that mountain chain another formation commences, which is the Silurian system of Murchison.

To which of his particular subdivisions they should belong he was in doubt. He felt, however, it was possible they might be the equivalent of Murchison's Llandeilo flags (Upper Cambrian).

The oolitic limestones and siliceous strata toward the west of the Cumberland Mountains he thought to rest upon a continuation of the Silurian system, more generally known under the name of "mountain limestone." This he made to extend over the whole of middle Tennessee to a few miles east of the Tennessee River.

In his seventh annual report he announced that the region about Nashville was composed of strata belonging to the Silurian system, and mentioned the fossils which he considered as characteristic of the lowest strata. In this report he gave a detail colored geological map of Davidson, Williamson, and Maury counties.

Troost's collection of fossil Echinodermata containing all his types and species described in what is known as Troost's list of 1850, together with the unfinished manuscript relating thereto, passed after his death in 1850 into the custody of the Smithsonian Institution, by which it was handed over first to Agassiz, and several years later to James Hall, to be put into shape for publication. For reasons unknown to the public this work was delayed year after year, until, after the death of Hall, in his turn (in 1894), it once more came into the possession of the Institution. In the meantime all that was new had been elsewhere described. Thus, through sheer neglect, Troost was robbed of much of the credit to which he was justly entitled.

Hitchcock on Drift Phenomena in North America, 1842.

In 1842 Dr. Edward Hitchcock read an important paper before the Boston meeting of the American Association of Geologists on the Phenomena of the Drift in North America, which is particularly interesting at this time as showing the gradual evolution of the present theory from that of the Noachian-deluge idea advocated by earlier writers. Hitchcock's views had, of course, been influenced by those of such men as Charpentier, Agassiz, Buckland, and Murchison, and he expressed at the outset the conviction that nearly all geologists would "agree in the principle that the phenomena of drift are the result of joint and alternate action of ice and water." To express this joint and alternate action he made use of the term "glacio-aqueous."

In this paper Hitchcock devoted some 50 pages to a description and discussion of, first, transported bowlders; second, smooth, polished, and striated rocks; third, embossed rocks; fourth, valleys or erosion; fifth, moraines; sixth, detritus of moraines; seventh, deposits of clay and sand; eighth, contortions of the stratified deposits; ninth, terraced valleys; tenth, fractured rocks; and eleventh, organic remains, after which he proceeded to discuss the theories of the various European authorities and state his agreement or objections to the same. He objected to the theory of Lyell to the effect that the results observed by him in North America were produced by floating icebergs derived from glaciers formed on mountains as the land gradually emerged from the ocean, because, first, it failed to account for the lower temperature which was necessary; second, because there was no evidence that the glaciers descended from the mountains; and third, because the deposits of vegetable matter derived from land plants showed that the continent must have been above sea level long before the drift period. The theory of De la Beche, which supposed the contents of the northern ocean to have been precipitated over the countries farther south by the elevation of the polar regions, Hitchcock regarded as possibly applicable to the low countries of Europe, but not to New England, since it would require a rise of the ocean amounting to some 6,000 feet, and he could find no facts to justify such an assumption, although recognizing the fact that the aqueo-glacial agency had operated well over the summits of the White Mountains.

To Agassiz's theory, which supposed an immense accumulation of ice and snow around the poles during the Glacial period and a consequent sending out of enormous glaciers in a southern direction, followed by floods of water and transportation of icebergs on return of a warmer period, he likewise took exception, since he was unable to conceive how such effects could be brought about; nor, indeed, could he understand how such causes could operate when the land was rising from the ocean and the water consequently retreating, as it must have been, to account for the various observed phenomena—such phenomena as would necessitate the occurrence of water loaded with ice and detritus floating for centuries at least over a large part of the earth's surface.

He likewise objected to Maclaren's "ingenious amalgamation" of Lyell and Agassiz's theories, but failed himself to suggest one perfectly satisfactory.

His paper showed a very clear insight into what had taken place, but an inability, with the information at that time available, to account for it in a satisfactory manner. Thus, in describing the striæ found by himself on the top of hills and mountains like Monadnoc, he wrote:

> Could immense icebergs have been stranded on the northern slope of the hills and afterwards, by the force of currents, have been driven over the summits; 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?

He regarded the moraines as deposited by floating icebergs and the linear forms observed as identical with the osars of Sweden. The fine blue stratified clay, often overlaid by sand, so characteristic of the upper valleys of the rivers in the glaciated areas, he regarded as silt deposited in temporary lakes formed by the damming of valleys by drift materials. After considering the phenomena as observed by himself and weighing all the theories advanced from time to time by the authorities quoted, he summed up the matter in the following words:

> Is it not possible that the phenomena of the drift may have resulted from all the causes advanced in the theories under consideration. * * I feel * * * that the proximate cause of the phenomena of drift has at last been determined, namely, the joint action of water and ice.

This is true Hitchcock conservatism.

In 1842 an expedition under Captain Powell was sent out by the Secretary of the Navy to survey Tampa Bay, Florida. Through the influence of the National Institute, in Washington, T. A. Conrad was allowed to accompany the party for the purpose of examining into the geology of the region. Conrad remained on the coast some three months, his results being published in the American Journal of Science for 1846.

Conrad's work in Florida, 1842.

From paleontological evidence Conrad was led to consider the limestone of the Savannah River in Georgia between Savannah and Shell Bluff as Upper Eocene, and thought that very probably the prevailing limestone of Florida would be included in this division. He also found evidence to lead him to believe that a considerable post-Pliocene elevation of the whole Florida peninsula had taken place, and that the Florida keys were a product of this movement.

D. D. Owen on the Geology of the Western States, 1842.

At the fourth annual meeting of the Association of American Geologists and Naturalists D. D. Owen read a paper on the geology of the Western States, including under this designation the region of the Ohio Valley. Abstracts of this paper appeared in the American Journal of Science for 1843. At the November (1842) meeting of the Geological Society of London Mr. Lyell presented for Doctor Owen the same paper, which was afterwards published in the journal of that society under date of 1846. It seems proper, therefore, that this paper should receive consideration here, particularly since Owen attempted a correlation of the American rocks with those from Europe. As published, the paper was accompanied by a colored geological map

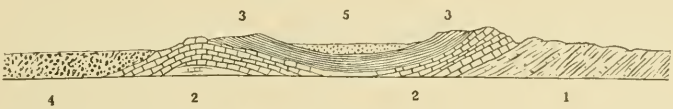


FIG. 32.—General section across the Western States. (After D. D. Owen.) 5, diluvium; 4, marl and greensand, probably cretaceous; 3, bituminous coal formation; 2, carboniferous limestone of Europe; 1, probable equivalents of the Silurian rocks.

of the Ohio Valley and the generalized section shown in fig. 32. The attempts at correlation, it should be noted, were founded on paleontological data. The limestones immediately underlying the coal (3 of the section) he considered to be the equivalent of the European Carboniferous. These rested upon a series of rocks, the upper one hundred feet of which Hall had assigned to the Devonian. The middle and lower beds Owen regarded as the equivalent of the English Upper Ludlow, as defined by Murchison. Below this he found shales which he believed to be equivalent to the English Lower Ludlow and the New York Marcellus shale. The shale-bearing rock he regarded as the equivalent of the Wenlock formation of Murchison.

The fundamental rocks of the Ohio Valley he considered as the equivalents of Murchison's Lower Silurian, the lower 75 to 100 feet corresponding to the Llandeilo flags and the rest to the Caradoc sandstones. The corresponding formations of New York appeared to be the Trenton limestone and shale, representing the older series, and the Salmon River and Pulaski sandstone, the rest.

Perhaps the most important outcome of the geological surveys of Pennsylvania and Virginia and certainly, from a strictly scientific standpoint, the most important and far-reaching conclusions, were those put forward by W. B. and H. D. Rogers in a paper read before the Association of Geologists and Naturalists in 1842, entitled On the physical structure of the Appalachian chain as exemplifying the laws which have regulated the elevation of great mountain chains generally. They called attention to the fact that the chain consists of a broad zone of very numerous ridges of nearly equal height, characterized by their great length, narrowness, steepness of slope, evenness of summit, and a remarkable parallelism. They divided the chain on topographical and structural grounds into nine distinct divisions, consisting of alternating straight and curved portions. They noted the remarkable preponderance of southeastern dips throughout the entire length, although the general trend of the chain was northeast and southwest. This was particularly characteristic of the portion along the southeastern or most disturbed portion of the belt, but toward the northwest dips in the opposite direction became less steep and more numerous.

H. D. and W. B. Rogers on Appalachian Structure, 1842.

They accounted for the phenomena of these dips by assuming them to be due to a series of unsymmetrical flexures, presenting in most instances 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 northwest side of every concave turn; so that, when viewed together, a series of these flexures has the form of an obliquely undulating line, in which the apex of each upper curve lies in advance of the center 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 parallelism and have a nearly uniform inclination of from 45° to 60° toward the southeast. This they described as a *doubling-under or inversion* of the northwestern half of each anticlinal flexure. Crossing the mountain chain from any point toward the northwest, they noted that 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 farther 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 side of each anticlinal axis gradually diminish and approach more and more to equality, until, in the great coal field west of the Allegheny Mountains, they finally flatten down to an almost absolutely horizontality of the strata at a distance of about 150 miles from the chain of the Blue Ridge or South Mountain.

This work, so far as it relates to the structure of the chain, has been improved upon in recent times only by the discovery of enormous overthrust faults in the southwestern portions. Their ideas regarding the origin of the chain have not, however, so successfully withstood the work of the modern physicists. They assumed that this difference in the dips was due to a combined undulatory and tangential movement of the earth's crust, which was propagated from the southeast toward the northwest; that is, they regarded the various ranges composing the chain as actually stiffened waves or billows of crustal matter comparable to the waves of less viscous matter, like water or lava. Their views may be best understood by direct quotation:

> We assume that in every region where a system of flexures prevails the crust originally 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 dikes occur, and to it we trace the far greater variety which there occurs in the size of the flexures.

The date of the Appalachian uplift they put subsequent to the formation of the Coal Measures, as being the final paroxysmal movement which terminated "in that stupendous train of actions which lifted the whole Appalachian chain from the bed of the ancient sea."

At this same meeting of the Association H. D. Rogers gave an important paper on the origin of the coal beds. He here took the ground that the singular constancy in thickness of the Pittsburg coal bed and its prodigious range were strongly adverse to any theory of accumulation by drift. His idea was that the area now covered by the coal was once an extensive flat, bordering a continent, beyond which lay a wide expanse of shallow but open sea; that these low flats were occupied by peat bogs derived from and supporting a luxuriant growth of Stigmaria, while along the land margin and the drier areas were conifers, Lycopods, and tree ferns. The Stigmaria would thus form a uniform mass of pulpy peat admixed with leaves and other easily transported débris of the trees along the shores, but free from trunks and coarse branches.

H. D. Rogers on the Formation of Coal, 1842.

To account for the shaly and sandy partings of the coal beds and their numerous impressions of plants, he imagined a sudden sinking of the land, producing thus a tidal wave from the open sea, carrying destruction to the forest growths, and on its return dragging back and spreading out over the sea bottom, and hence over the accumulated peat beds, sand, gravel, and silt, together with floating trunks of trees, all of which go to make up the roof slate and other partings in the beds. A period of tranquillity followed; another bed of peat accumulated, and so on. His theory differed from those of Buckland, Beaumont, Lyell, and others in excluding from the coal-making materials the trunks and branches of the more woody trees and the catastrophic interruptions in the growing processes due to earth sinkings and earthquakes.

He further accounted for the difference in volatile constituents between the coal of the eastern and western beds on the supposition that the former were debituminized by the action of steam and gaseous matter emitted through the crust of the earth and cracks and crevices formed during the undulation and permanent bending of the strata, resulting in the formation of mountain ranges.

Prof. W. B. Rogers, at this same meeting of the association, had an important paper on the connection of the thermal springs, in Virginia, with the anticlinal axes and faults. He recognized the work of the European geologists in connecting similar phenomena with areas of terrestrial disturbance, and then proceeded to show that, with but few exceptions, the thermal springs of the Appalachian region issue from the steep dipping or inverted strata on the northwest side of the anticlines. From this he deduced the general law that the decidedly thermal springs of Virginia issue from the lines of anticlinal axes or from points very near such lines. These views he regarded as in harmony with those of Arago and Bischoff. From those of Daubeny they differed, seemingly, in that the latter regarded such springs as indicative of volcanic

W. B. Rogers on Thermal Springs, 1842.

eruptions going on in a covert and languid manner under certain parts of the range. But Daubeny, it must be remembered, carried his views to an extreme, regarding the uplift of the chain itself as due to these same volcanic forces.

J. P. Couthouy on Coral Growth, 1842.

In 1842 there appeared in the Proceedings of the Boston Society of Natural History a paper by J. P. Couthouy, one of the naturalists of the Wilkes Exploring Expedition, in which an attempt was made to show that the distribution of coral growth in the ocean was limited by temperature. This paper brought forth very promptly a reply from Dana, who, while agreeing as to the facts and theories, claimed that he (Couthouy) had simply borrowed the idea from him; that the explanation "was originally derived from my manuscript, which was laid open most confidentially for his perusal while at the Sandwich Islands in 1840." The assertion was, of course, denied by Couthouy with equal promptness, but it must be confessed that the evidence, so far as it is available, favors Dana's claim.

Dana, it should be remarked, was led, from his observations while on this expedition, to agree with Darwin as to the formation of atolls (annular coral reefs), but could not agree with him regarding regions of subsidence and elevation. He found nothing which to him supported the idea that islands with barrier reefs were subsiding, while those with fringing reefs were rising.

Byrd Powell's work in the Fourche Cove region of Arkansas, 1842.

In the summer of 1842 Dr. W. Byrd Powell, of Little Rock, passed, of his own volition, some six weeks in a study of the geology of the Fourche Cove region, his results being published in a pamphlet of 23 pages and map, by the Antiquarian and Natural History Society of Arkansas. The Doctor at the time of his writing occupied the position of lecturer on phrenology and geology. Whatever may have been his qualification in the first-named subject, as a geologist he was no whit above the majority of workers of his day. The rocks of the cove and their association were described in considerable detail, the prevailing syenite being called granite, although he noted that it contained no quartz. He differed with Featherstonhaugh, however, in assuming, and wrongly, that the rock was primitive and not intrusive. To a supposed transitional form of greenstone into basalt he gave the name *Cornean*. The other rocks noted were basaltic clinkstone, amygdaloid, gneiss, etc. Some of his observations are open to question. Less than a gill of mica from the gneiss, he announced, yielded him half an ounce of metal, which he considered as mostly iron. He further remarked that the hornblende rocks of the region contained a large percentage of iron, which was chiefly, if not wholly, native; also that they contained native lead and a little silver.

The organization of the geological survey of the State of New York in 1836 has already been noted. Annual reports were issued regularly during the period of its existence, but with one or two exceptions the results can be best summed up in a review of the final reports as they appeared in 1842-43. Of these final reports, which were issued in quarto form, Mather's, comprising 639 pages, with 46 plates, in part colored, and including a geological map, was one of the most voluminous.

State Geological Survey of New York, 1837-1843.

The first geological district, to which Mather was assigned, embraced twenty-one counties, extending from the northeast of Washington County between lakes Champlain and George southwesterly to the Susquehanna River so as to include the counties of Washington, Saratoga, Schenectady, Schoharie, and Delaware, and all of the State east and south of this line.

Mather's Work in New York.

Mather thought to have recognized seven periods of elevation and disturbance of the strata, exemplified in the district assigned to him. These he described as follows:

First. One preceding the laying down of the earliest fossiliferous rocks, which gave rise to the primary Highlands of the Hudson and the primary mountains of Saratoga and Washington counties. On this he found the Potsdam and Calciferous sandstones and black limestone resting unconformably.

Second. One which preceded the deposition of the Helderberg limestone, which he found lying unconformably on the upturned earlier rocks. This manifested itself mainly in the Hudson Valley and included the Highlands and Westchester County.

Third. One subsequent to the deposition of the rocks of the Ontario division, the effects of which he thought to recognize from Green Pond Mountain through Bellevale Mountain, Goose Pond, Sugar Loaf, and Skunnemunk Mountains, and along the Shawangunk Mountains.

Fourth. One subsequent to the deposition of the Catskill division and even the coal formation. This disturbed all the pre-existing rocks in New York east of the Delaware. To it he ascribed the bending and wrinkling of the coal formations in Pennsylvania, Maryland, and Virginia. The era of disturbance was regarded as between that of the coal and the New Red sandstone.

Fifth. A period of disturbance at the end of the deposition of the Long Island division and before the deposition of the Quaternary.

Sixth. A period between the drift and Quaternary by which the land, without deformation, was lifted to about the level of the Quaternary formations.

Seventh. A period after the deposition of the Quaternary by which a large part of the land was lifted 100 feet above the level of the oceanic waters.

He thought, also, to recognize four periods of metamorphic agency, though, singularly enough, his metamorphism was that of contact by igneous masses only, and hence his periods those of igneous intrusion. To the then ordinarily accepted causes of folding, elevation, and depression, as steam and elastic vapors in a high state of tension, the contraction of the earth by secular refrigeration, or the undulatory action of the fluid interior, combined with tangential force—Mather added a fourth. He conceived that, as the earth is a cooling and shrinking body and revolving with increased rapidity owing to its diminished diameter, the ocean, being fluid, would not immediately partake of this increased velocity, and, therefore, as the earth revolved from west to east, a current of greater or less strength would set to the westward over the whole ocean, but strongest at the equator. The inertia of the solid mass of the interior of the globe would also cause it to press to the westward with a power dependent upon the rapidity of rotation. Given, then, lines of weakness where yielding would take place, motion and distortion or elevation might follow. If the interior were fluid and the solid exterior floating upon it, a change in the velocity would produce still stronger effects and changes of latitude of masses of the earth's surface affected in this way would result. Evidences of this were seen in the wrinkled and folded strata.

Some 75 pages of Mather's report were given up to a description and discussion of the phenomena of the drift. He concluded that the transport of the drift and the production of scratched surfaces were contemporaneous, the drift itself being transported in part by currents and in part by ice, itself drifted by the currents. The period of the drift and that of the Quaternary deposits were separated by a partial submergence of the land; and further, the periods of the drift were periods when the currents were stronger than at the present time. He conceived this to be due to a collapse of the crust of the globe upon its nucleus by refrigeration, causing an acceleration of the velocity of rotation, "and this a consequent disturbance of the form of equilibrium of the spheroid of rotation, which would be compensated by the flow from the polar regions and an accelerated flow of the equatorial regions." This sudden acceleration of the ocean currents he felt would be sufficient to cause the transportation of vast quantities of detritus-laden ice from the polar regions southward.

The large amount of drift scattered over the central and northern Mississippi region he ascribed incidentally to ice-laden currents from Hudson Bay and the polar seas which, flowing over the northern part of the United States, would be met by the warm waters of the Gulf Stream, causing them to deposit their loads. The warm current flowing northward would be superimposed on the cold current, the latter continuing southward beneath it, transporting the finer materials such as now occupy the lower Mississippi Valley. It may be added that Mather's disposition to overload and overwork the Gulf Stream is somewhat amusing. Not merely did he ascribe the glacial drift and the New Red sandstone deposits to this agency, but he would have the entire sedimentary series of the New York system dependent on the same causes. Thus, writing of these rocks: "And we can perceive no region from which such a vast amount of mineral matter can have been abraded and washed away * * * unless it has been brought by the equatorial and polar currents in their ceaseless flow through all time since the ocean has occupied the surface of the earth." Again: "And these depositions seem to have been formed in a kind of eddy produced by the meeting of the flow of warm waters of the Gulf Stream through the Mohawk Valley with the polar current through the Champlain and Hudson valleys." To the presence of this cold polar current on the east he attributed also the comparative paucity of fossil remains in these rocks when compared with those same horizons to the west, and to the same joint action of polar and equatorial currents, the formation of the coal beds. The equatorial current, he argued, performed a circuit around from New Mexico along the Rocky Mountains, a part flowing into the polar sea and Hudson Bay and the remainder through the northern part of the United States and southern part of Canada, where it again divided, one part flowing over and through the St. Lawrence Valley and the remainder over the Mohawk Valley and along the Blue Ridge around once more to the Mississippi, where it would rejoin the same stream, a polar current meantime flowing through the St. Lawrence and Hudson valleys to the valleys of the Red River of the North and the Mississippi. The meeting of these currents at particular points would produce eddies and consequent stagnation of the current. The transported organic matter, becoming water-logged, would sink to the bottom. This mode of formation, he thought, would account for the presence of tropical vegetation in the polar regions.

The white, red, mottled brown, and blue clays and variegated sands of Long and Staten islands he regarded as the geological equivalents of certain beds of New Jersey underlying the drift and Quaternary and of Cretaceous age. The materials he thought to have been derived from the breaking down of the gneissic, granitic, and other crystalline siliceous rocks which extend parallel to the Atlantic chain from Georgia to Maryland and reappear again in Connecticut and Rhode Island, extending probably into Massachusetts. This material, to him, bore evidence of transport from the southwest, and he believed the Gulf Stream, as before, to have been the transporting agent, its velocity being checked by the southward-traveling polar current. These cold currents sinking to the bottom would not be conducive to growth of animal life, and hence the beds are comparatively nonfossiliferous.

Mather believed that during the Quaternary division of time a vast inland sea occupied the basin of the St. Lawrence and Hudson valleys, and that during this time the clays and marls were laid down, the water having only a very moderate flow; that subsequently the country was raised en masse to a height of from 300 to 1,000 feet. This elevation he conceived to have been sudden, causing strong currents to flow through the channels communicating with the ocean, depositing sand, gravel, and bowlders in their eddies. (See further on p. 394.)

He also believed that the limestones, that are frequently crystalline white and variegated marbles in the western part of Vermont, Massachusetts, and Connecticut, were metamorphosed forms of the Mohawk limestone and Calciferous sandstone; that they were, in short, rocks of the Champlain division, but much more highly altered and modified by metamorphic agency than Taconic rocks. It should be said that, while using the term "Taconic" and describing the rocks and their distribution, Mather stated distinctly that he regarded the Champlain division and the Taconic systems as the "same rocks, the latter somewhat modified in character by metamorphic agencies."

In describing the Taconic rocks separately I have yielded to the opinion of my colleagues who have considered them as interposed between the Champlain division and the primary. I can discover no evidence of any such interposition, but consider them as rocks modified by metamorphic agency and intermediate in their characteristics between the unchanged rocks of the Champlain division and those still more altered and crystalline along the eastern line of New York and in the western part of Vermont, Massachusetts, and Connecticut. (See also under The Taconic Question, p. 659.)

The trap rocks of the Hudson Palisades he looked upon as ancient lavas that had flowed through the rock fissures in dikes while this part of the continent was still beneath the waters of the ocean. These rocks and the associated red sandstones he rightly believed to be of the same age as those of Connecticut, Virginia, and Nova Scotia, though he wrongly put down the Lake Superior red sandstone as also a contemporaneous deposit.

Emmons's work in New York.

Emmons, who had charge of the second district, presented his results in a quarto volume of 437 pages, with 17 plates and colored sections. It was during this survey that he proposed the name New York Transition system for the stratigraphic series of rocks extending from the primary up to and including the Old Red sandstone. Subsequently this name was shortened by the omission of the word *transition*, and in this form was adopted by the other members of the survey. He classified the rocks of this system in ascending order as, first, Champlain division; second, Ontario division; third, Helderberg division; and, fourth, Erie division. The first, or Champlain, division included the Potsdam sandstone, the Calciferous sand rock, the Chazy and Birdseye limestone, the Isle la Motte marble, Trenton limestone, and Loraine shales. The second, or Ontario division, included the Medina sandstone, green shales, and oolitic iron ore, now known as the Clinton ore, the Onondaga salt and plaster rocks, and the Manlius water lime. The third included the Pentamerus lime, the Oriskany sand, Schoharie grits, and Helderberg limestone. The fourth included the Marcellus and Hamilton shales, the Tulley lime, Genesee slate, and the Ithaca and Chemung slates and grits.

He regarded the transition rocks of Essex and St. Lawrence counties as equivalent to the graywacke series of European authorities. The so-called primitive limestone—the peculiar, coarsely crystalline, serpentinous limestone occurring in Essex County—he conceived might be an eruptive rock in which the carbonic acid had been retained by the pressure of superincumbent masses, the experiment of Sir James Hall, as he believed, bearing him out in this. The occurrence of plumbago he also regarded as favoring the igneous origin of the limestone, since plumbago is itself so often produced in furnaces.

He believed the agent of drift transportation to be water and ice. The bowlders he thought to be the work of icebergs, but he did not regard the striations and polishing as due to them, since the bottom of the ocean is not bare rock but covered by débris; and, moreover, icebergs would not move in straight lines (a point which some more recent writers have quite overlooked.) The bergs might act as agents of transportation, he argued, but not of erosion. According to his ideas, the drift-covered region was, during the drift period, depressed,

the country low and connected at the north with a wide and extensive region, giving rise to large rivers, which flowed in succession over different parts of the region lying between Champlain and the St. Lawrence. These rivers were wide, shallow, and swift in some parts of their courses, and frequently found new channels. They communicated with the Atlantic on the south through the Champlain, Hudson, and Mohawk valleys. They bore along ice loaded with sand, pebbles, etc., which scratched and grooved the surface of rocks over which they flowed, and were the agents, also, of perforating the rocks in the form of potholes.

Emmons was, at this time, a catastrophist, going so far as to assert that the deep canyons in the Potsdam sandstone, like the Au Sable chasm, were "opened by some convulsion of nature."

It was while connected with the New York State survey that Emmons conceived the idea that a series of obscure rocks, forming a belt some fifteen miles wide along the western border of Berkshire County, and lying along both sides of the Taconic Mountains, were distinct from any of the so-called primary rocks, and lay below those of the New York system. He therefore proposed, on stratigraphic grounds, to raise these rocks to the dignity of a system by themselves, which should be called the Taconic system. Inasmuch as the controversy which arose over this new system raged vigorously for nearly half a century, the subject is considered worthy of a special chapter. (See p. 659.)

Vanuxem's report on the third district, a volume of 306 pages, consisted of little more than an uninteresting account of the geographic

JAMES HALL.

State Geologist of New York.

distribution of the various rocks and their fossil contents. In fact, it fell short of what one would be led to expect from a perusal of his earlier papers. His district, it should be noted, comprised the counties of Montgomery, Fulton, Otsego, Herkimer, Oneida, Lewis, Oswego, Madison, Onondaga, Cayuga, Cortland, Chenango, Broome, Tioga, and the eastern half of Tompkins.

Vanuxem's work in New York.

As a matter of petrographical interest, it may be well to note that the serpentine described by Vanuxem [first in his third annual report (1839) and last in his final volume (1842)] as occurring near Syracuse, and concerning the origin of which he was then somewhat in doubt, was in 1844 described as an igneous rock, and as the only mass of the kind in the vicinity of the Salt Spring. This fact seems to have been quite overlooked by Williams in 1887, when, working with all the appliances of modern petrography, he showed the rock to be an altered peridotite.

To James Hall was assigned the fourth district in the New York State Survey at the close of the first season, as already noted (p. 344). This comprised fifteen counties, including all that part of the State lying west of the parallel of Cayuga Lake and between Lake Ontario on the north and Pennsylvania on the southeast. The area includes the least disturbed portions of the State, those portions where the rocks lie in a beautiful consecutive series, extending from the Medina up to and including the Chemung and affording means unrivaled for the unraveling of the stratigraphy of the continent. It is doubtful if, at the time this district was assigned to Hall, he himself realized its possibilities—certainly his collaborators did not. Indeed, at the time of Vanuxem's transfer and Hall's promotion the region was regarded as one of little promise and was willingly relinquished to the youngest and least experienced of the force.

Hall's Work in New York.

Hall's report, appearing in 1843, comprised 683 octavo pages, with 19 plates, including a colored geological map of the State and the United States as far west as the Mississippi River.

Hall adopted the term New York system, as suggested by Emmons, to include all the oldest fossiliferous rocks of the State, excluding the Chemung and Catskill. As defined by him it would be the equivalent of what was embraced in the *transition* of Werner. It likewise included Sedgwick's Cambrian, Murchison's Silurian, and the Devonian of Phillips, omitting the Old Red sandstone.

Concerning this he wrote:

Nowhere is there known to exist so complete a series of the older fossiliferous rocks as those embraced within the limits of the State, and for the reason that in New York, where the means of investigation are best afforded and where the whole series is undisturbed, there is manifested the most complete and continuous succession, showing but one geological era for the deposition of the whole. In that era the earth first witnessed the dawn of animal life and ages of its greatest fecundity in marine organisms and the approach of the period when it became fitted to support a vegetation so luxuriant and universal, of which no modern era has afforded a parallel.

Hall, it should be noted, in this report, gave precedence to paleontological characters over all others in distinguishing the sedimentary strata, but recognized the fact that lithological characters must not be wholly disregarded, a fact to which he had previously called attention (p. 383)

Changes in the lithological features of a rock * * * which may render observations unsatisfactory or doubtful are usually accompanied by greater or less change in the nature of the fossils. In no case, therefore, are to be overlooked either of the three important facts and characters, viz: Lithological character, order of superposition, and nature of the contained fossils.

At the time of making his report Hall's views regarding the drift were still somewhat hazy. That he did not accept Agassiz's doctrine of a vast ice sheet is very evident. Thus he wrote:

That blocks of granite either enclosed in ice or moved by other means have been the principal agents affecting the diluvial phenomena; that they have scored and grooved the rocks in their passage and, breaking up the strata and mingling themselves with the mass, have been driven onward, carrying everything before them in one general mélée. That such may have been the case in some instances or in limited localities can not be denied, but that it ever has been over any great extent of country will scarcely admit of proof.

The erratics he felt had been dropped from time to time by ice floes and at a period apparently distant from that of the general drift.

Hall was at this time evidently a catastrophist and regarded the drift soils, terraces, and the deep valleys and water courses as due to the violent action of water, which may have been caused in part by a sudden submergence and the rapid passage of a wave over its surface. His views were, indeed, in many respects, little, if any, in advance of those held by Mitchill twenty-five years earlier. Like Mitchill, he conceived of an inland sea bounded by and held back, in this case, by the Canadian Highlands on the north, the New England range on the east, the Highlands of New York and the Alleghenies on the south, and the Rocky Mountains on the west. These presented a barrier of from 1,000 to 1,200 feet above the level of the ocean until broken through by the St. Lawrence, the Susquehanna, the Hudson, partially by the Mohawk at Little Falls, and perhaps also by the Connecticut.

But, to whatever cause we attribute the phenomena of the superficial detritus of the fourth district, the whole surface has been permanently covered by water, for it seems impossible that partial inundations could have produced the uniform character and disposition of the materials which we find spread over the surface.

Hall apparently failed at first to realize the efficacy of subaerial erosion, and thought that the immense amount of denudation which had taken place in his portion of the State could only have been accomplished beneath the ocean, when it entirely covered the surface of the country and was subject to tides and currents like the present ocean.

Thus we may conceive this whole extent of country to have been submerged beneath the ocean for a long period; and that in its subsequent elevation it has been washed by the advancing and retiring waves, which have worn the deep indentations in the limestone cliffs and broken up the edges of the strata.

Hall was born at Hingham, Massachusetts, in 1811, and studied under Eaton at the Rensselaer Polytechnic Institute, graduating in 1832, after which he served for a short time as librarian, and was then appointed assistant to Eaton, at a salary of $600 a year.

Sketch of James Hall.

His first systematic work in geology was done under the patronage of Stephen Van Rensselaer in St. Lawrence County. With the organization of the State geological survey in 1836 he was appointed assistant to Emmons, but, after the withdrawal of Conrad, was placed in charge of the fourth district—the level, uninteresting western portion of the State, which he was told was good enough for a young man of twenty-five. The region was not the western New York of to-day; roads were less numerous and less carefully made; exposures were rare and poor. It was necessary to wade along streams for miles to gain fragments which were to be pieced into tentative sections; the people were suspicious, fearing some new scheme for increasing the taxes; but none of these things moved him; as in later years, difficulties only increased his determination. So his is the only one of the four final reports which deals broadly with the problems of the young science, and, though upon the contemned fourth district, it is the only one which has endured with authority and become a classic in geological literature.

FIG. 33.—James Hall.

The final withdrawal of Conrad from even the paleontological work left Hall almost sole master of the field, which he for a time filled so completely that he came to regard it as his own, and resented fiercely any intrusion upon his domain. This resentment and his desire to gain priority in all matters relative to Paleozoic paleontology caused him at times to resort to methods so questionable as to rouse the antagonism of nearly every paleontologist in America,[a] and subjected him to criticism of the severest kind. Undoubtedly a portion of the hatred and opposition to him which early became manifest was the outgrowth of that peculiar jealousy which the poet Riley has so aptly set forth in his humorous rhyme:

And I've known some to lie and wait,
And git up soon and set up late,
To find some fellow they could hate
For going at a faster gait.

[a] See Meek's comments relative to Hall's work in Iowa, and also statements on p. 367 relative to the Troost collection.

Much of it was, however, unquestionably fully justified.

His disposition to down an opponent through sheer weight of personal authority rather than by proof or argument sometimes resulted in placing him in laughable and awkward positions before his audience, but from which he always emerged unembarrassed. Thus it is told of him that at the Buffalo meeting of the American Association for the Advancement of Science a member rose to question a statement of his to the effect that three species of Spirifer characterized three zones of the Chemung formation, the gentleman affirming that, so far from this being the case, the three species could often be found upon one slab, indicating that they belong to the same zone. This Hall emphatically denied, and declared that if such a slab could be shown him, i. e., with the three species associated, he, Hall, would eat it. The next day such a slab was actually produced, though it is not upon record that Hall was called upon to redeem his promise.

He was a man of tremendous physical energy, whom no amount of opposition could down, and on the failure of the legislature in 1850 to make the necessary appropriations for a paleontological survey of the State he carried it on for a time at his own expense, even when this involved the sacrifice of his private means.

Stevenson would have us believe that the fundamental feature of Hall's character was "child-like simplicity united to self-confidence and indomitable energy." With reference to the last-mentioned qualities no one will take exception.

Knowing what he wanted he took a direct line, with little regard for anybody or anything which might be in the way to oppose. * * * He deceived his opponents by always telling the truth, something strange to politicians, but in time they came to understand him well, and strong men sought combat simply to measure strength, as in gladiatorial contests of olden time. Almost invariably he was victorious, but victory was often worse than defeat, for it converted into life-long enemies men who before had been merely indifferent. * * * He held his place for almost two-thirds of a century through no favor of man, but solely because he refused to be displaced.

For the benefit of those who, after the science of paleontology was well upon its feet, were disposed to claim it as a branch of biology, it may be well to remark that with Hall the problems of geology were always uppermost.

His quartos on the New York paleontology are his monument, and the casual observer is liable to see in him a biologist rather than a geologist, but until his later years he was a geologist. His studies were from the standpoint of one seeking to determine relations between the physical and biological conditions in order to solve problems of correlation. The great problems of geology, not those of biology, were uppermost in his mind until less than twenty years ago. His presidential address to the American Association for the Advancement of Science in 1857 (see p. 499), was so far in advance of the time as to be thought not merely absurd, but mystical, yet to-day it is recognized as one of the most important contributions to one of the most difficult problems in physical geology. Even in his later years, when biological problems had assumed their proper importance for him, he would have resented an intimation that he was any less of geologist than before.

Fifteen quarto volumes, comprising 4,539 pages and 1,081 full page plates of fossils, stand as an enduring monument to his industry, a record which never has, and presumably never will be, surpassed in the annals of American geology.[a]

In 1841 Hall, fresh from his work on the geological survey of New York, made a tour through the then western State of Ohio to the Mississippi River, with a view of furthering the work of Vanuxem in 1829 relative to the identity of certain of the western formations with those of New York. As a result, he claimed that the rocks seen near Cleveland were "perfectly identical with those of the middle portion of the Portage group," and that the rocks of the Chemung group, now known to be Waverly, appeared near Newbury and Akron. The Cliff limestone of the Ohio geologists he regarded as the equivalent of the Helderberg series of New York, or at least of the Onondaga and Corniferous members.[b] Perhaps the most important of his generalizations was the following:

Hall's Work in Ohio, 1841.

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. 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 through successive depositions, often of very different nature; yet, at the same time, these may not have had a very wide geographical range.

[a] Prof. Charles Schuchert informs me that if to the above are added his miscellaneous publications in octavo the number of pages of text published during his life may safely be set down as not less than 10,000. Large as are these figures, they were, however, exceeded by the celebrated Bohemian paleontologist Barrande, who issued during his life 18 quarto volumes, comprising 5,568 pages of text and 798 plates of fossils, besides leaving manuscript and material for at least 10 volumes more, of which 4 have been issued since his death.

[b] At that time, the Corniferous, Schoharie, Cauda-galli, Oriskany, and the Onondaga, or Salina and Waterlime, were considered subdivisions of the Upper and Lower Helderberg.

He further wrote:

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, 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.

This is apparently the first clear enunciation by an American geologist of what are now generally recognized as well established geological principles.

It was but natural that Hall, while geologist of the fourth district of New York, should write concerning Niagara and its gorges. The views of Bakewell, Rogers, and Hayes have been already noted in these pages. Hall in his State report (1841), but more in detail in the Boston Journal of Natural History for 1842, covered the ground in a manner much more thorough and scientific than any of his predecessors.

Hall's Views Concerning Niagara, 1842.

Hall announced at the outset his disagreement with Doctor Daubeny,[a] who considered that the terrace or escarpment at Lewiston was produced by a fault, as he found no evidence whatever of even the smallest disturbance.

He noted the abrupt change in the direction of the stream at the Whirlpool, and also the gravel-filled channel extending from this point to St. Davids, but, singularly enough, failed to realize that this may have been the one-time channel of the Niagara. He felt, rather, that this ravine was excavated by the power of the waves of the sea, aided probably by a stream which may have been of very insignificant proportions.

The fact was, however, recognized that the river was at that time carving out its own channel, and the existing gorge from the falls to Lewiston was due to the same cause.

In 1841, after several years of agitation, there was established a geological survey of Canada, of which W. E. Logan was put in charge in the spring of 1842, the sum of £1,500 being appropriated for the purpose of carrying out the work. During the season of 1842 Logan spent several weeks in examining portions of the coal fields of Nova Scotia and New Brunswick, and made his famous section of the Coal Measures at the South Joggins, which gave the details of nearly the whole thickness of the coal formation, some 14,500 feet, including 76 beds of coal and 90 distinct Stigmaria under-clays. Logan remained at the head of this

Establishment of a Geological Survey of Canada, 1842.

[a] Daubeny was professor at Oxford, England.

survey until 1869, when he resigned, to be succeeded by Selwyn (see p. 549). During this period he submitted sixteen reports, dealing mainly with stratigraphic and economic subjects, and in 1863 a summation of his results under the caption of The Geology of Canada (p. 517).

Issachar Cozzens's Geology of New York, 1843.

Among the early members of the New York Lyceum was one Issachar Cozzens, a chemist and geologist, who has left as his main claim to recognition here an octavo volume of 114 pages and 9 plates, entitled A Geological History of Manhattan or New York Island, together with a map of the Island and a suite of Sections, Tables, and Columns for the Study of Geology, particularly adapted to the American Student. This was published in 1843. The map and sections were all hand-colored, the latter somewhat gorgeously, and included, aside from those relating to New York Island proper, sections of Staten Island; one across the Palisades on the west side of the Hudson River; one from Stony Point, on the Hudson River, through Dunderberg Mountain in New York; one from Brenton Reef to Portsmouth, Rhode Island, and one of Niagara Falls, the latter showing the origin of the falls through the gradual undermining of the softer shales and the breaking down of the harder limestones above.

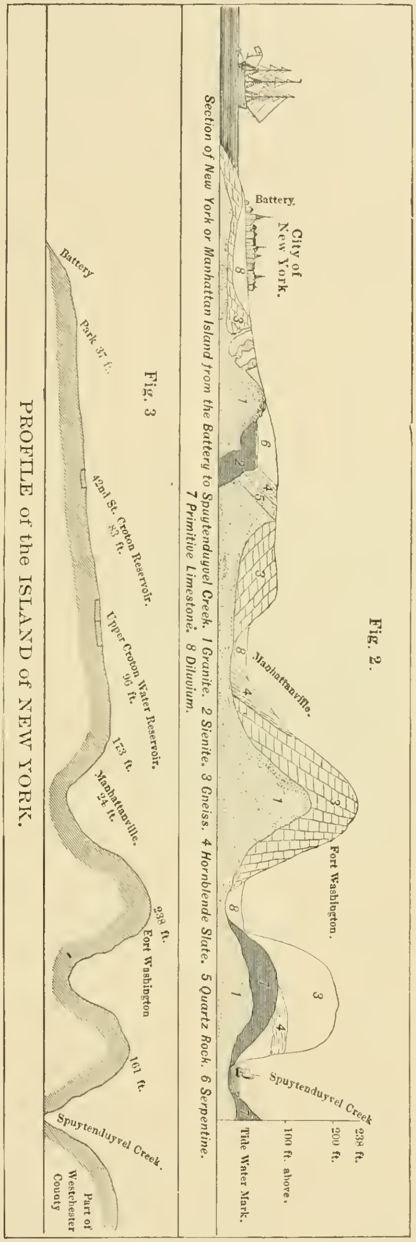


Fig. 34.—Profile of the Island of New York.

The rocks of Manhattan Island proper were classed as (1) granite, (2) syenite, (3) gneiss, (4) hornblende slate, (5) quartz rock, (6) serpentine, (7) primitive limestone, and (8) diluvion.

In the various sections given the vertical distances are grossly exaggerated, and the rocks piled on top of one another without any evident consideration of their original position; nor is there in the text any indication that the author considered at all the problems relating to original horizontality, uplift, and erosion. The red sandstone associated with the New Jersey traps (Triassic) he considered as Old Red, but the impressions of fossil fish that had been reported as found therein he regarded as rather from overlying beds—from "one of the upper members of the Coal Measures which lie above it." The Triassic conglomerate of Maryland and Virginia was also incidentally referred to the Coal Measures. This seems a little strange when we consider the previous work of his collaborators, Redfield and Hitchcock.

It is stated in his preface that the work was first undertaken for his own amusement and study, and it is possible that his influence can not be gauged simply by this one publication.[a]

Lawrence's Geology of the Western States.

In 1843, also, there was published by Byrem Lawrence a geological map and descriptive pamphlet of the Western States. This was designed for popular use, and was claimed to be the first attempt of its kind. The "Western States" at that date included nothing west of the Mississippi Valley. "The West," he wrote, "has no mountains nor even hills, except such as have been produced by the action of running water * * *. The rocks here have never been broken by violence nor tilted up as in the East, but lie apparently horizontal in the sides of the hills." The drift he described in some detail, its source recognized and its cause attributed to water and ice. "It is probable there may be some analogy between the whole matter and the icebergs of the present day."[b]

Ruffin and Tuomey's work in South Carolina, 1843.

In 1843, too, the noted Edmund Ruffin, agricultural surveyor of South Carolina, published a report of the commencement and progress of his survey, in the form of a small volume [of 120 + 55 pages], which naturally related largely to agricultural matters. It contained, however, a list of the invertebrate fossils of the State as then known and numerous analyses of the marls. He noted that nearly the entire country above the lower

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[a] In the annals of the Lyceum of Natural History for 1867, Mr. R. P. Stevens had a paper read in 1865 on the past and present history of the geology of New York Island. In this, after reviewing the work of H. H. Hayden, Maclure, Akerly, and Cozzens, he gave the results of later observations by himself in the 75 to 100 miles of artificial sections exposed since Cozzens's time. He showed the island to be a portion of the main land of Westchester County cut off by a profound fault. The rocks enumerated were chiefly gneiss, which he considered metamorphosed Taconic, cut by granite, and interbedded with limestone.

[b] Lawrence is credited in Darton's bibliography of American geology with but two very brief geological papers—on Coal in Arkansas and the Geology of Arkansas—published in New Orleans in 1851 and 1853, respectively.

fall line of the rivers was occupied by granitic rocks and their residual soils.

The first attempt at a systematic geological survey of South Carolina was inaugurated in 1844 with the appointment of Michael Tuomey as State geologist. The first report, an octavo pamphlet of 45 pages with an appendix, was submitted in November of the same year. This was devoted mainly to economic considerations, and, aside from a few notes on rock weathering, contained little of general interest. His final report, which appeared in 1849, will be noted later.

Tuomey was born in Ireland in 1805, and went to England when about 17 years of age, shortly afterwards coming to America. He first settled near Philadelphia, going thence to Maryland, where he served for a time as a tutor in a private family. He entered the Rensselaer school in New York, and after graduation went South, serving first as an engineer on a railway in North Carolina and afterwards as a teacher in Virginia.

Sketch of Tuomey.

His love for natural history led him to make collections of fossils, which brought him in contact with Sir Charles Lyell, James Hall, J. D. Dana, and others, and he shared with Rogers the honor of discovering the infusorial beds near Richmond and Petersburg.

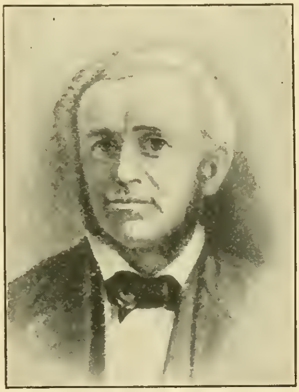


Fig. 35.—Michael Tuomey.

In 1844 he became State geologist of South Carolinia, as already mentioned, and, in 1847, was appointed professor of geology, mineralogy, and agricultural chemistry in the University of Alabama; in 1848 receiving in addition the appointment of State geologist. As a teacher Tuomey is represented to us as possessing in a remarkable degree the faculty of interesting the student, those, even, who took no particular interest in the subject-matter of his lectures. His native Irish wit did much to render his lectures entertaining, especially to those who were not the victims of it, he being particularly unmerciful in his rebukes and exposures of shams and affectations.

His most important publications are his official reports on the geology of South Carolina, and his joint report with Dr. F. S. Holmes, of Charleston, on the Pliocene fossils of that State, the latter of which appeared in 1855.

Prior to the introduction of the microscope and the study of rock structures by means of thin sections (about 1870) views regarding metamorphism, particularly such as are due to sheering stresses in the older crystallines, were naturally somewhat vague. With rocks too fine of grain to allow a determination of their structure and mineral composition by the unaided eye, only mode of occurrence could be relied upon to give a clew to their origin, and it was not until the thin sections made it possible to sometimes trace a distinct gradation from schistose and foliated rocks of decidedly metamorphic aspect into massive eruptives of the same ultimate composition that a feeling of doubt began to arise in the minds of observers regarding the assumed sedimentary origin of the gneisses and crystalline schists.

Dana's Views on Metamorphism, 1843.

It was during this prematinal period, as Rogers might have termed it, that J. D. Dana came out with a suggestive paper in the American Journal of Science on the analogies between the modern igneous rocks and the so-called Primary formations and the metamorphic changes produced by heat in the associated sedimentary deposits. The conclusions arrived at were based upon observations made during the Wilkes exploring expedition, and the exciting cause of a paper at this time would appear to have been the somewhat varying views recently put forth by Lyell.

Dana argued that: (1) The schistose structure of gneiss and mica slate was not necessarily an evidence of sedimentary origin; (2) that some granites having no trace of a schistose structure may have had a sedimentary origin; and (3) that the heat producing metamorphism was not applied from beneath by conduction, but was rather due to heated waters of the ocean which permeated the rocks. As confirmatory of the first he called attention to the parallel arrangement of the minerals and the consequent platy structure, with a tendency to split along certain lines, which were sometimes found in volcanic and other igneous rocks. The possibility of a schistose structure due to dynamic (shearing) causes was not, however, suggested.

His argument for the possible metamorphic origin of certain granites was based upon the fact that some of the basaltic tuffs observed by him in the Andes and in Oregon had become so indurated that their fragmental origin was almost wholly obscured. He felt that if rocks of this type could be so remodeled or rehardened as to be scarcely distinguishable from the parent rock, sedimentary deposits of granitic origin might undergo a like change.

His argument against metamorphism by dry heat was enforced by calling attention to the low conducting power of stone, which is such that heat, even to the point of fusion, may be transmitted only a few inches. "Lavas may be heated to a red heat within a yard of the surface and still be so cool above that the bare foot may walk upon them." He believed that subterranean waters or water on sea bottoms might become so heated by "volcanic fires" as, on permeating the rocks, to bring about the metamorphism. This, of course, would mean that the gneissic rocks were not necessarily deep seated (hypogene), as held by Lyell, but analogous to other rock formations deposited and solidified at or near the surface.

In a paper read before the fifth session of American Geologists and Naturalists in 1844, Prof. Edward Hitchcock described a trap tufa differing from "common trap" in being conglomerate and apparently carrying organic remains. He believed that this was produced before the main ridges of trap along the Connecticut River, by precursory outbursts of pumice, scoria, ashes, and melted matter falling over the bottom of the ocean, where it became admixed with sand and gravel. After this layers of sandstone accumulated over it, and finally the main ridges of trap were protruded through the strata, tilting them up.

Hitchcock on the Trap Tufa of the Connecticut Valley and on Inclination of Strata, 1844.

He regarded the dip of the sandstone in the valley as due in part to elevation by the protrusion of the trap and in part to the lifting and lateral movements of the adjoining primary ridges. He felt, however, that the sandstone might have been originally deposited on a slightly inclined plane. This last view brings up a matter which seems often to have seriously troubled the earlier geologists, and which, so far as the literature shows, was never solved for itself, but became lost sight of as other and satisfactory means of accounting for the phenomenon were observed. This relates to the inclined position of strata—how much of it was due to original deposition and how much to upheaval. Cleaveland, it will be remembered, in his work on geology and mineralogy, 1816, expressed a doubt as to whether the inclined position of strata was original or due to some powerful cause which had elevated them from horizontality. Maclure in 1825 suggested that the dip, so far as the transition rocks were concerned, might result from their having been laid down on a primitive floor, concerning the position of which nothing was known. Hitchcock, it will be noticed, with his usual caution, felt that both causes might have been instrumental in producing the dip observed.

At the same session at which Hitchcock read the paper noted above, Benjamin Silliman, jr., presented a report On the Intrusive Trap of the New Red Sandstone of Connecticut. His conclusions were to the effect that the sandstone was let down from suspension in water in the inclined position which it now occupies and that it had suffered no change in dip, excepting in immediate connection with the injection of the trap rocks. He considered it probable that the strata were deposited by a primeval ocean current setting from the southwest and west. Subsequent to this accumulation and consolidation the lower primary rocks were disrupted, the igneous rocks injected through the fissures and distributed along the lines of least resistance in the sedimentary strata—that is, along and up the plane of the dip, thereby lifting the strata parallel to the dip from the beds on which they had before reposed. At the same time there were produced in the upper strata fissures and transverse cracks which were filled with the molten trap. This injection he thought was probably continued during a long period, but all referable to the same geological epoch and anterior to the elevation of the strata in which it occurred.

After the deposition and injection ceased and the elevation of the present continent had commenced, denudation, induced by a northerly current, set in, the current itself being due to the flowing off of the oceanic waters incidental to the elevation of the present continent. By this denudation the soft shales and other materials were removed and the trap ridges developed. Thus, deposition, intrusion, uplift, and erosion were all included within a single epoch.

Early speculations regarding the origin of the earth, though largely fanciful, were founded upon the brief outline of a series of events as chronicled in the first chapter of Genesis. Theories regarding earth development and its probable destiny other than its catastrophic annihilation through Divine wrath, as a punishment for sinful man, were slow to appear. When such did appear, however, they were founded upon a much more scientific basis.

H. D. Rogers on the Atmosphere of the Coal Period, 1844.

That a mutual reaction was going on constantly between the superficial portions of the earth and its surrounding atmosphere was doubtless realized by all of those who wrote on the weathering of rocks and the formation of soils; but, so far as known to the present writer, H. D. Rogers was one of the first of American geologists to show by direct calculation that the earth had been in the past, as at present, robbing the atmosphere of some of its constituent parts and gradually storing them up in its solid crust.[a]

At the Washington meeting of the American Association of Geologists and Naturalists in May, 1844, Professor Rogers submitted a communication on the probable constitution of the atmosphere at the period of the formation of the coal. He estimated that the amount of carbon existing in the atmosphere to-day in the form of carbonic acid would be only sufficient to furnish through vegetable action about 850,000,000 tons of coal, while the probable quantity of this substance in existence, all of which must have been elaborated from the ancient atmosphere, was nearly 5,000,000,000 tons; that is to say, about six times what the present atmosphere would produce. So great a reduction in the carbonic acid, implying a corresponding augmentation of oxygen, is felt to be a matter of great interest in geology, as showing that every modification in the constitution of the air had adapted it to the development of animals progressively higher in the scale of organization.

Of all the New England States Vermont was the last to become infected with a desire for a geological survey, and it was not until

[a] Vanuxem in 1827, while connected with South Carolina College, pointed out the probable change in the atmosphere during geologic time through the absorption by the earth of nitrogen and oxygen, and also the probability of a warm, moist climate during the period of coal formation. (American Journal of Science, XII, 1827.)

1844 that the final steps were taken resulting in the appointment of Prof. C. B. Adams as State geologist. Adams was educated at Phillips Academy and Amherst College, and subsequently attended the theological seminary at the last-named place. In 1836 he became a tutor at Amherst and for a brief period was assistant to Professor Hitchcock in his work on the geological survey of New York. When appointed State geologist of Vermont he selected Zadock Thompson as his chief assistant, Denison Olmsted, jr., and later T. Sterry Hunt aiding in mineralogy and chemistry. Rev. S. R. Hall, of Craftsbury, was employed to look after the agricultural features. Up to March, 1848, the survey continued in a fairly prosperous condition, a large amount of material being collected, both in the way of specimens and notes, but at the session of the legislature for this year appropriations were for some reason withheld and the work stopped. Four reports in all were issued, the last a mere pamphlet of eight pages.

C. B. Adams's Work in Vermont, 1844.

The purpose of the survey, as stated in the first report, was to collect and analyze the soil, the simple minerals, both of economic and scientific importance, and to make investigations into the character and limits of the geological formations. The reports on the whole were extremely fragmentary. Doctor Adams dying before the manuscript of the final report was prepared, a large part of his work was lost, this mainly owing to the fact that he took his notes in a "peculiar shorthand, which only he could read." As suggested by Professor Thompson, it would have required more labor to decipher his notes than to go over the ground anew.

Fig. 36.—Charles Baker Adams.

The second annual report was prepared—as was not infrequently the case at that date—in the form of a general treatise on geology, and began with an elementary chapter which dealt with all subjects relating to geological phenomena, whether applicable to the State or not. The views advanced were those given by the text-books of the period and need not be mentioned in detail. An ideal section from the first report is, however, reproduced here as illustrating equally well the rough method of picture making with which the early workers had to content themselves and the crudity of ideas relative to the earth's crust and interior. He would, indeed, be regarded as a novice in geology to-day who would not at first glance inquire what supported the mass of solid material represented as resting upon the molten lava, yet this question does not seem at this time to have even presented itself for consideration. A little space was devoted to the subject of the connection between geology and the Bible, to meet the wants of the "many well-meaning persons" who were disturbed by a supposed incongruity between the principles of geology and the Mosaic narrative. A very abstruse explanation of concretionary structures was offered, Adams failing, as did many of his contemporaries, to discriminate between concretionary structure as it is now understood, and certain forms assumed by igneous rocks and due to contraction in cooling. Thus he considered columnar structure in basaltic rocks as a peculiar form of concretion which was due to lateral pressure such as might exist between spheres compressed at the sides.

Agassiz's glacial theories had been apparently without effect, even if they were known, and icebergs were considered as sufficient to account for all the phenomena of the drift.

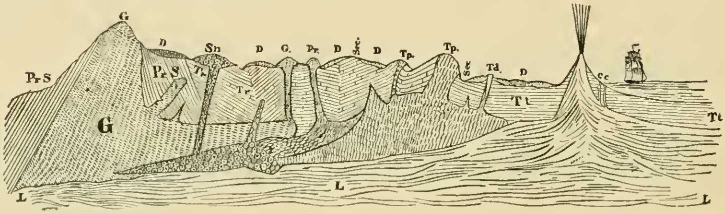


FIG. 37.—Ideal section of the Crust of the Earth. (After C. B. Adams.)

EXPLANATIONS.—Unstratified rocks of igneous origin: G, granite; Sn, seinite; Pr, porphyry; Tp, trap rocks; Td, a trap dyke; L, lava, with a volcano, *c c* being fissures through which the water of the ocean penetrates to the melted lava by its conversion into steam, causing earthquakes and eruptions. Stratified rocks (represented by parallel lines) of aqueous origin: Pr S, primary strata; Tr, palaeozoic rocks, or the oldest rocks which contain the remains of animals and plants; Sec, secondary rocks; Tt, tertiary strata; D, the superficial covering of sand, gravel, and loose stones, called "drift."

In 1847, the year before the closing of the survey, Adams had accepted a professorship at Amherst, and in 1853, in conjunction with Alonzo Gray, published as a text-book an Elements of Geology, a duodecimo volume of 350 pages. Here his geological work seems to have ceased. Indeed, from the date of the abandonment of the State survey he devoted himself mainly to zoology, and particularly to conchology, making large collections especially rich in West Indian and Central American forms. While at St. Thomas, on one of his collecting trips, he contracted yellow fever, from which he died in 1853. He is described as a man of sturdy build, medium height, with large, black eyes and black hair. A man of tremendous physical endurance, knowing neither fear nor what it was to be tired; but, withal, a quiet and self-contained demeanor.

Thompson, Adams's chief assistant, is represented to us as a man poor in this world's goods as well as in general health, and modest almost to a fault—one who from childhood had shown a passion for writing books. His first publications were almanacs, which he himself sold while traveling on foot about the country. It is told of him that when at one time interrupted by his clerk with an inquiry as to the prediction that should be made in the forthcoming issue for the weather for July, he replied somewhat testily, "Say 'Snow about this time.'" So it stood in the printed almanacs, as issued from the press, and, to the astonishment of all, including both printer and author, snow did fall in Vermont that year in the month of July.

Sketch of Zadock Thompson.

The industry of the man was remarkable. He graduated from the University of Vermont at the age of 27. He published an arithmetic, a geography and map of Canada for use in the common schools; became in 1832 editor of the Green Mountain Repository; wrote a history of Vermont, which appeared the same year; studied theology, and took deacon's orders in the Protestant Episcopal Church in 1836. He preached for a time and returned once more to his book writing, first publishing in three volumes a Natural, Civil, and Statistical History of Vermont; then a text-book on the Geology and Geography of Vermont; finally becoming an assistant to Professor Adams on the State survey in 1845, when his geological work really began.

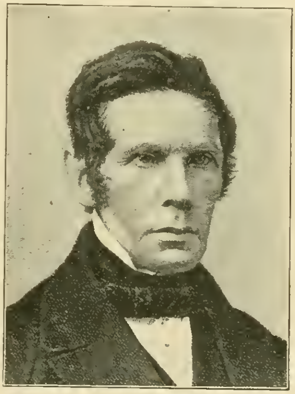


FIG. 38.—Zadock Thompson.

"Tall, angular, of a very quiet and sedate, yet very pleasant, manner, a man of most amiable and sweet temper, loved by all who knew him, and respected for his sound sense and accurate judgment." Such is the picture given us of him, who certainly was one of the most remarkable men of his times although his name may not stand the highest in the annals of geology.

Under the caption of "Description of a singular case of dispersion of blocks of stone connected with the drift in Berkshire County, Massachusetts," Dr. Edward Hitchcock described in the American Journal of Science for 1845 a remarkable train of glacial bowlders extending from Fry's Hill in the Canaan Mountains, of New York, southeasterly into Massachusetts for a distance of some 15 or 20 miles.

Hitchcock's Description of the Richmond Bowlder Train, 1845.

The lithological nature of the bowlders was such that they could all be traced to a common source, though described as forming three somewhat meandering trains extending from Fry's Hill above mentioned, through the adjoining valley, and upward over an elevation of 800 feet at the State line, across the Richmond Valley and over Lennox Mountain, 600 feet in height, to and over Beartown Mountain, 1,000 feet in height.

Naturally, so striking a phenomenon excited investigation, and, naturally, too, Doctor Hitchcock, in the then existing condition of knowledge regarding glacial transportation, found difficulty in accounting for the same. He recognized the similarity of the trains to the lateral glacial moraines described by Agassiz in his *Etudes sur les Glaciers*, which had appeared five years previously, but could not conceive of a glacier traveling directly across the intervening ridges, even were the mountains in the vicinity of sufficient altitude to give rise to the same. Neither did the consideration of river drift or floating ice afford him a satisfactory conclusion. "In short, I find so many difficulties on any supposition which I may make that I prefer to leave the case unexplained until more analogous facts have been observed."

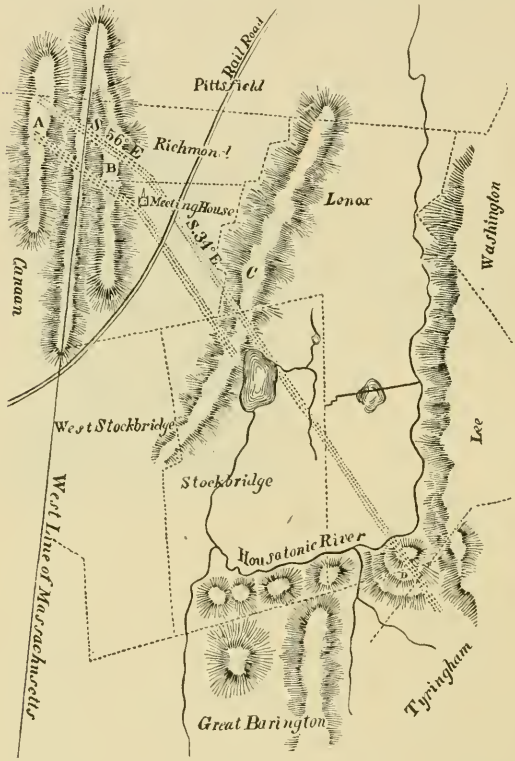


Fig. 39.—Richmond Bowlder Train. (After E. Hitchcock.)

Unsatisfactory and apparently unimportant as the paper may, at first thought, seem, it is mentioned here on account of the extraordinary explanation of the phenomenon offered by the Rogers brothers three years later (see p. 403).

In the American Journal of Science for 1845 W. W. Mather, whose work in New York and Ohio has been already mentioned, published a paper on the physical geography of the United States in which he still further elaborated some of the interesting and rather unique ideas regarding the origin of the secondary rocks and the elevation of islands, continents, and mountain chains which he there put forth. These may be referred to in considerable detail.

Mather on the Physical Geology of the United States, 1845.

Mather again argued on the basis that the earth is a cooling body, contracting, and hence undergoing an increased velocity of rotation upon its axis. The oblateness of its spheroidal form, due to the increase of centrifugal force, would therefore induce a flow of water from the polar to the tropical regions, and as the earth revolved from west to east these currents from the poles would bend more and more to the westward as they advanced to lower latitudes. On the other hand, the water in the Tropics, being gradually expanded through heat, would tend to flow off toward the polar regions.

These currents he regarded as having acted throughout all the time since the ocean occupied its present bed, and to them he would ascribe the mechanical distribution of many of the sediments making up the Secondary rocks. Considering only those currents that constitute the Equatorial, the Gulf Stream, and the Labrador Current in the Atlantic, he thought to show that the materials constituting the immense mass of sedimentary rocks between the primary ranges north of the Great Lakes and the Gulf of Mexico, and between the Blue Ridge and the Rocky Mountains, were deposited within the great eddy due to their interference.

The red sandstone formations extending from Carolina to Stony Point on the Hudson he believed to have been formed through the transporting power of the Gulf Stream, its northward extension having been cut off by a polar current flowing through the Champlain and Hudson River valleys. The loosely consolidated material now classed as glacial drift he seemed also to regard as having been transported and deposited through the same agency. The coal beds of the eastern and central portions of the United States he regarded as formed at the bottom of the ocean in which great eddies occurred, and where plants brought from the Tropics and other sources would float and circle about until they sank. He noted that these beds were based upon a sandstone which at the outcrop of its edges on the coal basins was much coarser and sometimes a conglomerate or coarse pudding stone, while through the center of the basins it was much finer. This fact denoted to his mind a stronger current on the exterior of the coal basins than within its area.

Concerning the regions over which the polar currents were supposed to have flown, and from whence, as a consequence, were derived the materials for the sedimentary rocks, he could say little from actual observation. Drawing for his materials mainly on the writings of travelers, though acknowledging that such might be faulty, he nevertheless pictured a scene of barrenness of the entire region north of the St. Lawrence and Great Lakes and from Newfoundland to the Stony Mountains such as is equaled only by that given by H. H. Hayden in his attempt to account for the deposits of the coastal plain (p. 256).

Although the quotations from travelers lack that accurate examination that is necessary to a determination whether the surfaces thus described have been exposed to the action of violent and long-continued currents, yet they have their weight. When considered in connection with the effects of known physical causes, it is rendered more than probable that the currents under consideration have flowed from the polar regions toward the equator and from the Tropics toward the poles when this continent was beneath the ocean, and that the matter which composed the deposits of the sedimentary rocks of the United States was washed away by these great equilibriating currents from the bed of the ocean, from reefs, islands, and coasts, and finally deposited from suspension over the great area where we now find it exposed to observation.

The probable cause of the elevation of the land he thought to be secular refrigeration accompanied by contraction, whereby a gradually accumulating tension was finally overcome by a yielding of the solid strata, such being regarded as paroxysmal and productive of earthquakes. At the same time a sudden increase of the velocity of the earth's rotation would result, and this in turn would increase the flow of the ocean currents above mentioned.

In attempting to account for the overturned character of the folds in the mountain chains of the eastern United States, he seems to have actually outdone the Rogers brothers in fecundity of ideas. He wrote:

> Paroxysmal elevation and the action of inertia offer a satisfactory explanation of the folded axes and eastwardly dip. Suppose the sudden elevation of a mountain mass one mile in height, or more distant from the axis of rotation than it was before its elevation. It would still retain the linear velocity it had when a mile nearer the axis of rotation, while the proper linear velocity at this increased distance would be $\frac{3.1415}{24}$ miles, or 690 feet greater per hour than that which it had before its elevation. Inertia would therefore cause the mass at the top to press to the westward with a force proportional to its mass and the above-mentioned velocity, and at intermediate heights with a proportionally less momentum. If the strata be capable of yielding, they must, when elevated in highly curved wrinkles, tend to fall over westward as a consequence of the influence of inertia and the revolution of the earth from west to east on its axis.

Such a view from a man of Mather's training and at this late date certainly seems extraordinary.

Commenting further on the effects of centrifugal force, particularly upon bodies of different densities, he argued that as such is greatest under the equator, any subterranean force tending to elevate portions of the earth's surface by their elastic tension would here be most effective. In this way he would account for the supposed fact that most of the highest mountains are found within the Tropics. Reasoning along the same lines, he conceived it possible that fractures might be expected to develop in the direction of circles parallel to the equator at a distance intermediate between it and the poles, where the curvature resulting from the revolution of the earth would be greatest.

Conrad's Medial Tertiary of North America, 1845.

In continuation of his work begun in 1832, T. A. Conrad in 1845 issued his volume on the Medial Tertiary formations, the general plan of the work conforming closely to those which we have already considered (pp. 306, 320, and 354). In this latter work he described these formations as occupying a shallow but very extensive depression in the Cretaceous rocks, the most northern locality known being Cumberland County, New Jersey, whence it extended southward in a very connected series, spreading out over a large portion of the Atlantic seaboard.

The nature of the country, its strata, and fossils were described in detail. The most interesting part of the paper, from our standpoint, lies in his remarks on the theory of elevation and the age of the deposits. He regarded the formation of each Tertiary division and the final annihilation of its fauna as a very gradual operation, taking place in quiescent waters and having no connection with volcanic agencies or any violent movements of the earth's crust, but merely depending on changes of temperature.

In discussing the effects of these temperature changes he showed some peculiar ideas regarding the conductivity of rock masses and the effects of cooling. The cold penetrating deep into the igneous rocks beneath the surface, he thought, would result in a maximum amount of crystallization and expansion,[a] producing thereby a slight elevation of the crust. Since the cold penetrated gradually, he argued that the elevation would also be gradual, more appreciable, of course, during epochs of unusual cold. In brief, crustal elevation, he would have us believe, was induced not by volcanic agency, but by "the all-powerful and pervading influence of crystallization in the primary rocks." In this he followed what he calls the "sublime" theory advanced by Vanuxem. The idea that the abrupt change in the character of the animal life at the close of each geological epoch by a sudden fall of temperature was, however, avowedly the theory of Agassiz.

In connection with work pertaining to the Liberian Colonization Society, in 1845–1848, David Christy traveled extensively throughout the eastern and middle United States. Being a man of active mind and with a love for the sciences, he made many geological observations which were first embodied in a series of letters to Dr. John Locke and published in the Cincinnati Gazette. These were afterwards issued (in 1848) in pamphlet form, some 70 pages, with 5 plates of fossils and three geological sections: the first from Mine La Motte and Pilotknob, Missouri, to Hollidaysburg, Pennsylvania; the second from Lake Erie to Pensacola Bay, and the third from Richmond, Indiana, through Oxford, Ohio, to Beans Station, Tennessee.

David Christy's Geological Observations, 1845-1848.

It is impossible to say what portion of the information given in these letters can be claimed to be strictly the result of original investigation or observation. As stated by Locke in his introductory note, he "referred the geological formations to the Blue Limestone of Cincinnati as a kind of zero, informing us whether the rocks at any place are above or below that zero." Locke further states that he knew of "no other individual who has actually drawn approximate sections of the strata from the Atlantic to Iowa and from Lake Erie to the Gulf of Mexico; most of this work being the result of his own observations."

In a letter addressed to M. de Verneuil in 1847, relative to the

[a] As a matter of fact, crystallization in a rock magma would result in contraction.

erratic rocks of North America, Christy showed himself to have been a catastrophist. He believed that there had been two periods of elevation of the land in the history of the continent, with an intervening submergence. The second and last emergence he regarded as having been rapid and to have given rise to the swift currents which were instrumental in producing the drift.

Wislizenus's Explorations in Mexico, 1846.

In the spring of 1846, A. Wislizenus, a "German by birth and an American by choice," left St. Louis, Missouri, with the intention of making a tour through northern New Mexico and upper California for the purpose of examining into the geography and general natural history of the country. Unfortunately for his intentions, war between the United States and Mexico broke out while he was within the jurisdiction of the Mexican Government, and he was compelled to remain within the State of Chihuahua for a period of six months or until the arrival of the American troops, when he accepted a position in the medical department and returned with it by way of Monterey to the States.

Fig. 40.—Frederick Adolphus Wislizenus.

His opportunities for observation were, naturally, much less than was at first anticipated, and his geological report, amounting to but five pages, was published as a part of Senate Miscellaneous Document No. 26 of the thirtieth Congress, first session. In this report he noted that the bluffs on the Arkansas some 341 miles from Independence were of a grayish conglomerate limestone, containing fossils which "seemed to belong to the Cretaceous formation." Near Las Vegas he found a dark blue limestone with casts of *Inoceramus*, which were also relegated to the Cretaceous series. Near El Paso he noted the presence of a limestone containing the fossil coral *Calamopora* and the bivalve shell of the genus *Pterinea*, which, as a consequence, he considered as belonging to the Silurian formation. The presence of numerous eruptive rocks were noted and an outline map published, in which the lithological nature of the rocks was indicated. The map, it should be noted, comprised the area lying between the Arkansas and the Rio Grande rivers, but extended south and west of the latter as far as Monterey and Chihuahua.

Binney's Views on the Loess, 1846.

The fine silt-like character of the superficial deposits of the Mississippi Valley had frequently been noted by the various geologists who passed over the region, but it remained for Amos Binney, the conchologist, to give the first reasonably satisfactory account of its probable origin. At a meeting of the Boston Society of Natural History in April, 1846, Binney exhibited a collection of fossil shells from the so-called Bluff formation at Natchez, on the Mississippi, and announced the belief that the formation was analogous to the Loess of the Rhine Valley and a result of fluviatile action rather than attributable to the glacial drift.

In 1847 J. D. Dana, who from the beginning of his career had shown a disposition and ability to grasp the broader, more profound questions of geology, came forward with two papers which were beyond question the most important of the year. The first of these had to deal with the geological results of the earth's contraction in consequence of cooling and involved the acceptation on his part of the prevailing theory that the earth was once in a condition of igneous fluidity. After a full discussion of the subject and the views held by others, Dana announced it as his belief that the now oceanic areas were at one time the most intensely heated portions of the crust, and had, therefore, on cooling undergone the greatest amount of contraction, and that, further, the mountain ranges and main fissures along the oceanic borders are due to this same contraction. Such a theory, he felt, did away with the almost preposterous though prevalent idea that continents and mountains have been lifted up by a force acting from beneath, a force which could not be satisfactorily located and accounted for; a theory which would not account for the mountains retaining their positions, even did it offer satisfactory explanation for their first production.

Dana on the Geological Results of the Earth's Contraction and the Grand Outline Features of the Earth, 1847.

He showed, further, that the folding and faulting of the strata as described by the Rogers brothers in Virginia and Pennsylvania could be readily accounted for on the theory of a force acting laterally, and that such folds would have their steepest incline on the side farthest from the source of movement and would also be most abrupt nearest this source. The fact that such results were not in all cases uniform, he conceived as being due to variation in the thickness of the beds, to a want of uniformity in the materials, and inequality in the action of the force upon the different parts of the line along which it operated.

The geological epochs were regarded, as announced in this same paper, as perhaps due to the alternation of prolonged periods of quiet with those of more or less abrupt change, due to contraction. The idea that mountains might be produced by tides and paroxysmal movements beneath the crust (as advocated by H. D. Rogers) was set aside on the ground that such should have occurred at earlier periods, and, further, it would not account for the principal ranges in the east and west of the continent. In many of the views he here advanced Dana agreed with those previously advanced by the French geologist Prevost.

In the second paper referred to, on the Grand Outline Features of the Earth, Dana argued "that the great chain of mountains, as well as of islands, are interrupted ranges consisting of overlapping lines, either straight or curved, and that curves constitute an essential feature of the system." He showed that throughout the system of outlines presented by the earth northwest and northeast lines are prevalent, and that these lines are usually curved, instead of conforming to the direction of a great circle. He apparently accepted the theory that the course of mountain ranges, islands, and coast lines is attributable to the courses of former fissures in the earth's surface, and, in discussing the electrical, contractional, and other theoretical causes, suggested that if, as claimed, curves of magnetic intensity on the earth's surface are approximately isothermal lines, they must also be lines of equal cooling and hence of equal contraction and tension. But whatever may have been the origin of the fissures, he thought there could be no doubt but that a kind of cleavage structure, or at least capability of fracturing easily in two directions, was given the crust during its formation.

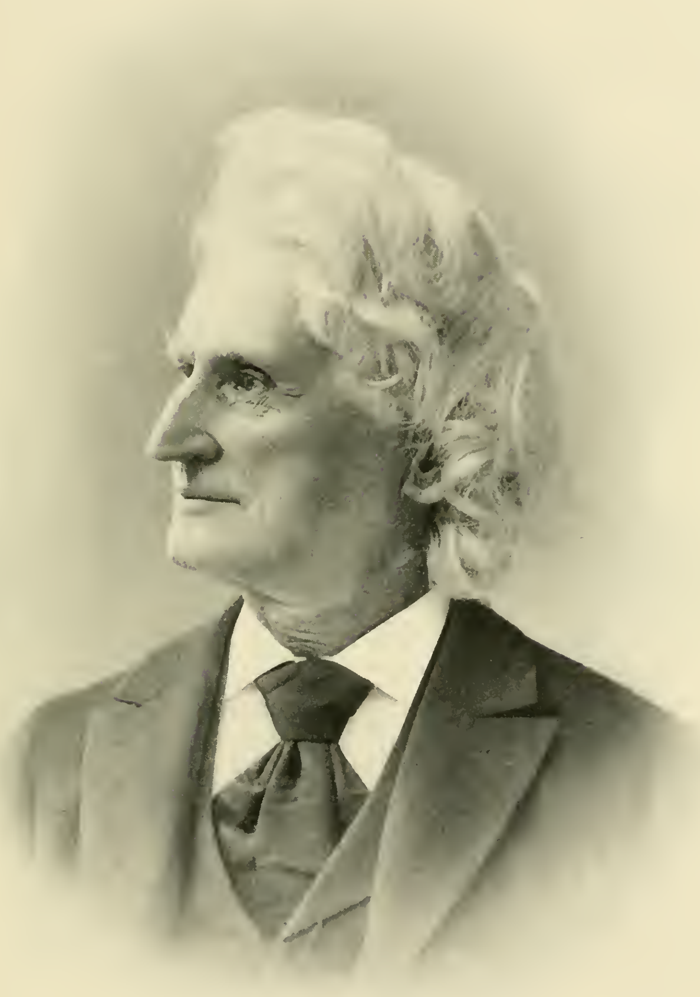
The conclusions which appear to flow from the facts that have been presented are as follows:

That the general direction and uniformity of the grand outline features of the globe may be in a great degree the simple effects of the earth's cooling, this operation resulting in (1) solidification, and under the circumstances, whatever they were, an attendant jointed structure or courses of easiest fracture, in two directions nearly at right angles with one another, both varying according to the rates of cooling in different parts; and (2) occasioning tension in the crust through the contraction going on beneath, with some relation to circular areas, but especially to large compound areas, which tension caused ruptures conforming or not to the lines of jointed structure according as the force of tension acted in accordance with this structure or obliquely to it. (3) The age of mountains can not, therefore, be determined necessarily by their courses; a different direction in a particular region in different ages is not improbable, since the same contracting area might exert its horizontal force in somewhat different directions at different epochs, or other such areas might cooperate and exert a modifying influence; and at the same time an identity of direction for different ages was to have been expected.

Sketch of J. D. Dana.

Prof. James D. Dana was born in Utica, New York, in 1813, and was, therefore, practically contemporaneous with James Hall. He became a student of Professor Silliman's in 1830 at Yale College, leaving in 1833, somewhat in advance of graduation, to avail himself of an offer to cruise in the Mediterranean, as instructor in mathematics to the midshipmen in the Navy.

The first paper in his bibliography was published in 1835 and gave an account of Vesuvius as seen by him during this trip in 1834. In 1836 he returned to New Haven, remaining for two years, the latter part of the time as assistant to Professor Silliman. It was during this time, scarcely four years after his graduation and when but twenty-four years of age, that he brought out his first System of Mineralogy,



JAMES DWIGHT DANA.

Professor of Geology, Yale College.

a volume of 580 pages, and a most remarkable work for the time and the conditions.[a]

From 1839 to 1842 Professor Dana served as geologist and mineralogist on the Wilkes Exploring Expedition, and for the first thirteen years after his return devoted his chief energies to the study of the material collected on the expedition and to the preparation of his reports, of which two—the volume on geology, 756 pages, 5 maps, and 21 plates (1849), and the one on crustaceans, 1,620 pages, with an atlas of 96 plates (1854)—are monumental. His labors, however, were not limited to the reports, for during the same period he prepared and issued three editions of the System of Mineralogy (1844, 1850, 1854) and two editions of the Manual of Geology (1848, 1857), besides writing numerous papers for scientific periodicals.

In 1846 Mr. Dana became an editor of the American Journal of Science, associated with Prof. Benjamin Silliman, who had founded it wenty-eight years before. His labors in connection with the Journal continued until the close of his life. In 1850 he was appointed professor of natural history in Yale College, and in 1864 the title was changed to that of professor of geology and mineralogy. His duties as instructor, however, he did not take up until 1855, but after this date, with some interruptions due to ill health, his active connection with the college continued until 1890. It is perhaps well to add that just before his appointment to Yale in 1850 he had been invited to a similar position at Cambridge, Massachusetts, in connection with Harvard College, but by the prompt action of a generous friend in the Yale faculty in providing the necessary funds he was induced to remain in New Haven and accept the "Silliman Professorship."

Fig. 41.—James Dwight Dana.

In 1859 long-continued overwork brought a breakdown of serious character and from which he never fully recovered, and although later some degree of health came back, he was always subject to the severest limitations until the end of his life. Only those immediately associated with him could appreciate the inexorable character of these limitations and the self-denial that was involved, not only in restricting work and mental effort, but also in avoiding intercourse with other men of science and friends in general, in which he always found the greatest pleasure. Little by little

[a] The "System" has now gone through six editions, though after 1868 the work was done mainly and finally wholly by his son, Prof. E. S. Dana, now professor of Physics and Curator of the Mineralogical Collection in the same university. The last edition, that of 1892, comprises 1,104 royal octavo pages with over 1,400 figures in the text.

the power for work was restored and by husbanding his strength so much was accomplished that, besides other writing, he was able to bring out in 1862 the first edition of his Manual of Geology, and in 1864 the Text-book of Geology, and four years later his last and most important contribution to mineralogy, the fifth edition of the "System." This last great labor, extending over four years, was followed by a turn of ill health of an alarming character and from which restoration was again very slow.

The years that immediately followed were filled with the same quiet labor, geological investigations in the field, the writing of original papers and books, the editorial work of the Journal, and his duties as a college instructor.

They were remarkably productive years, notwithstanding the difficulties contended against, notably his renewed illness in 1874 and 1880. A large number of important papers were published, chiefly in the Journal. New editions of the Manual of Geology were issued in 1874, 1880, and 1895; of the Text-book in 1874 and 1883; while a new geological volume called The Geological Story Briefly Told was issued in 1875, and one on the Characteristics of Volcanoes in 1890, after his second visit to the island. A second edition of his book on Corals and Coral Islands, the first edition of which appeared in 1872, was also brought out in 1890.

But it was not as an investigator and writer only that Dana achieved success. As a teacher he seems to have won the respect and regard of all with whom he came in contact, and to have left on the minds of students—even those who had no taste for geology—a lasting and favorable impression. Many of his sayings in class lectures were epigraphic: "I think it better to doubt until you know. Too many people assert and then let others doubt." Again, "I have found it best to be always afloat in regard to opinions on geology."

Nor can we regard him as merely a geologist. His work on crustaceans, comprising 1,620 pages, with an atlas of 96 plates (1854), shows that equal success could have been attained in the biological field had he chosen to follow it. The mental vigor and staying powers of the man were simply extraordinary, and it is not too much to say that he stands out head and shoulders above all his contemporaries, if not above all who preceded him. His interest never flagged; no problem was too large for him to grasp, no detail too small for his consideration.

H. D. and W. B. Rogers on the Richmond Bowlder Train, 1848.

It would seem quite extraordinary that two men who have done so much for American geology, whose work was really epoch making, who, without doubt, excelled any geologists of their time in ability to unravel the difficult structural problems of any region, should have been so extremely visionary in theoretical matters. The peculiar ideas of H. D. Rogers on the subject of the elevation of the Appalachians are elsewhere referred to. I wish here to notice their equally extraordinary ideas regarding the

Berkshire (Richmond) bowlder train, first brought to notice by Hitchcock (see p. 394).

According to the descriptions now given, the trains start, each from its particular depression in the summit of a high ridge, in Canaan, New York. Taking a direction S. 35° E., they cross the higher ridges and

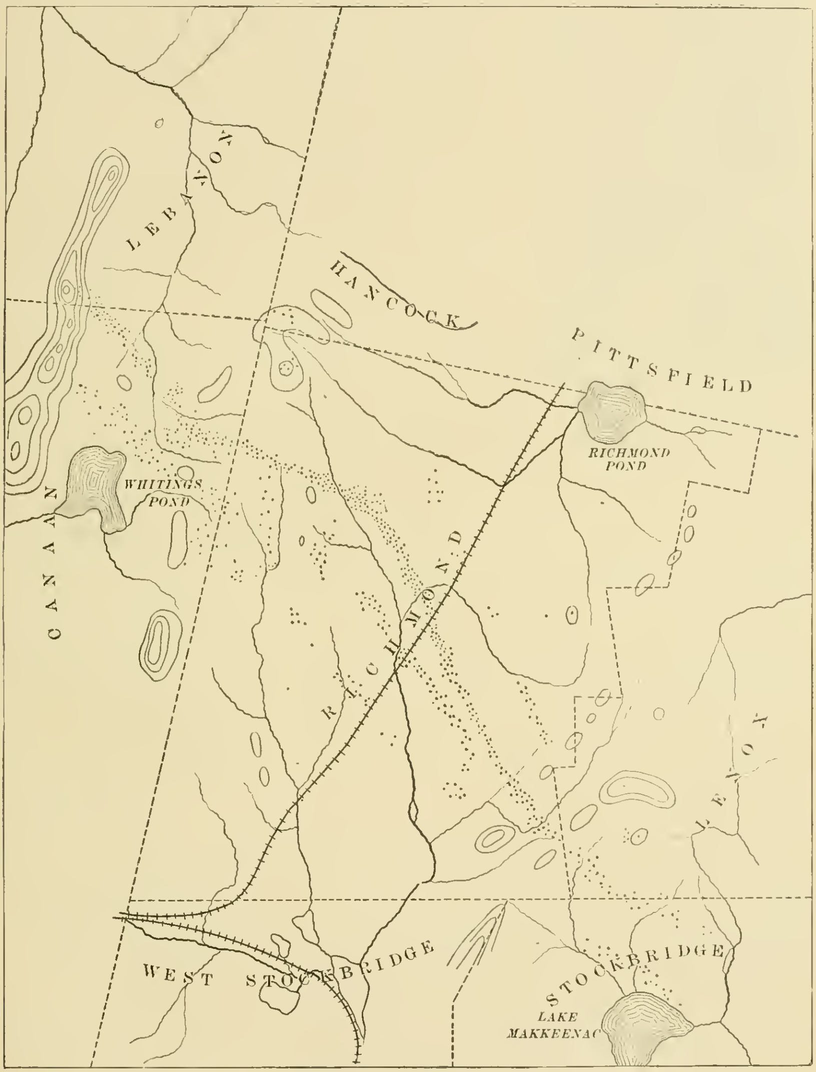


FIG. 42.—Sketch map of Richmond Bowlder Train. (After E. R. Benton.)

their intervening valleys, the longer for a distance of 20 miles and the shorter for 10 miles. The individual trains are neither of them more than 300 or 400 feet in breadth, and not over half a mile asunder. The transported blocks are of all sizes up to 20 feet in diameter, sharply angular, free from scratches, and all of the same lithological nature, identical with that of the ridge from whence they start. That such a dispersion of bowlders from a single point should have taken place regardless of contours is certainly enough to excite the interest of anyone. It is the means invoked by the two workers which have excited our wonder, however.

After exhibiting to their own satisfaction the inadequacy of either the iceberg or the glacial hypothesis to account for their production, the authors, in a paper before the Boston Society of Natural History in 1848, attempted to show how all the phenomena might be explained by the theory of a sudden discharge of a portion of the Arctic Ocean southward across the land. They discussed the important functions of the "wave of translation," showed its surpassing velocity and great propulsive power, and traced the influence of vehement earthquakes near the pole in dislodging the northern waters and ice and maintaining in the rushing flood these vast and potent waves. They then suggested that, at a certain stage of the inundation, the ice, previously floating free, might impinge with irresistible violence against the tops of submerged hills, and that the Canaan Mountain stood precisely in the position to take the brunt of the ice-driving flood as it swept down the long, high slope of the distant Adirondack and across the low, broad valley of the Hudson.

They then proceeded to show that, at the instant when some enormous ice island struck the crest of the mountain and scooped the trench which we there behold, a great vortex was produced by the obstruction thus suddenly thrown in the path of the current, which, endowed with an excessive gyratory or spiral velocity, was capable of sustaining and carrying forward the greater part of the fragments. As in the instance of the water spout and the whirlwind, the whirlpool would gather into the rotating column the projected blocks and strew them in a narrow path in the line along which its pendent apex would drag the ground.

The paper terminated with an application of this idea in detail, to the explanation of each important feature of these trains; to their deflection from a straight line; the intermission in the bowlders at certain places in the train, and the fact that some of the blocks have been violently broken at the moment previous to their final deposition.[a]

Truly there were catastrophists in those days.

We may anticipate here by stating that at the meeting of the American Association for the Advancement of Science in 1870, Prof. J. B.

[a] In 1852 the English geologist Lyell visited this region in company with James Hall, the former's views on the subject being published in 1855 in the Proceedings of the Royal Institution. He regarded the hypothesis of glacial transportation as out of the question, and apparently also that put forward by the Rogers brothers, for he made no mention of it. His own idea was that the large erratics had been transported to their present resting place by floating coast ice.

Perry read a paper on glacial phenomena, in which he referred to these trains incidentally, and argued that they were part of the true glacial drift—morainal material deposited by the melting of the ice sheet of the glacial epoch.

Prof. J. B. Perry's Ideas, 1870.

Again, in 1878, Mr. E. R. Benton studied the trains in considerable detail, and in the Bulletin of the Museum of Comparative Zoology published a detailed description and map of the region, from which the one given herewith is reproduced. Benton took the ground that the bowlders were deposited by the ice sheet of the glacial period at the time of its final melting, the direction of the striæ on the underlying rocks being here essentially the same as that of the bowlder trains. In connection with his investigations, Benton wrote to Prof. W. B. Rogers concerning the views above advocated by him, and received in reply the letter from which the following abstract is taken:

E. R. Benton's Work, 1878.

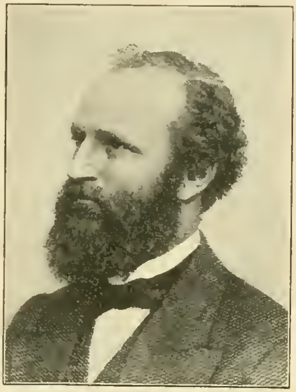


Fig. 43.—John Bulkley Perry.

At that time (i. e., when this paper was written) paroxysmal dynamics had still many advocates, and the attempted explanation may be interesting as a specimen of the bold type of speculation in which some of the early geologists sometimes ventured to indulge. But, for myself, I may say that long years of observation and study make me more distrustful of our knowledge of causes and more willing, in geology as in other things, to labor and wait.

It will be remembered that in 1844 Michael Tuomey was appointed State geologist of South Carolina, a position which he continued to hold until his appointment to the chair of geology, mineralogy, and agricultural chemistry in the State University of Alabama.

Tuomey's Final Report on the Geology of South Carolina, 1848.

A preliminary report has already been noted (p. 387). The final report appeared in the form of a volume of 293 pages in 1848. This, with the exception of the volume on the fossils of South Carolina, of which he and Doctor Holmes were joint authors, was the most systematic and pretentious of his publications.

This survey, like that of many of its predecessors in other States, was undertaken with a view of developing the agricultural resources of the State. The condition of the public mind toward pure science at the time is well reflected in the almost pathetic postscript of Mr. Tuomey to his preface, in which he simply states that, while the report was passing through the press, he was informed that the plates containing figures of fossils had not been considered essential by the committee on publication and were therefore omitted. The work comprised: (1) An introduction of 59 pages, given up, as was so often the case with these early reports, to general geological considerations and as applicable to any other region as that at hand, and (2) the report proper, comprising seven chapters (234 pp.) and an appendix of 56 pages, containing a catalogue of the fauna of the State. It also contained a geological map of the State, the first to be issued.

The introductory chapters are interesting only as reflecting the condition of geologic knowledge at the time. Tuomey estimated that our actual knowledge of the earth's crust extends to a depth of 15 miles, measured from the tops of the highest mountains. He adopted the Kant-Laplacean theory of the origin of the earth, and recognized slaty cleavage as distinct from joints and stratification, regarding it as resulting "from the tendency of the simple component substances of the rock to arrange themselves in crystalline forms at a time when the semifluidity of the mass permitted a certain degree of motion among its particles." The crystalline structure of the gneisses and other metamorphic rocks he regarded as resulting from a degree of subterranean heat which, although intense, did not destroy the lines of stratification or bedding which they received at the time of their deposition. In his table showing the order of superposition of fossiliferous rocks, he divided them into: (1) The Recent or post-Pliocene period; (2) the Tertiary; (3) the Newer Secondary or Cretaceous; (4) the Middle Secondary, including the Wealden and Lower Lias with the intermediate beds; (5) the Older Secondary, including the Triassic; (6) the Newer Paleozoic, extending from the Magnesian Limestone or Permian down to and including the Lower Carboniferous shales; (7) the Middle Paleozoic, including the Devonian; and (8) the New York System of Upper and Lower Silurian, including the Chemung and Champlain Division and intermediate formations.

In the part of the report relating to the geology of the State proper were chapters on the character of the surface rocks, beginning with a discussion of the granites and traps. Attention was called to their extensive decomposition, and the production of bowlders through decomposition along joint plains is described and figured. The occurrence of the flexible sandstone, or itacolumite, was noted, and it was rightly remarked that "the flexible portions of the rock seem to be in the incipient stages of disintegration." The gold and iron mines received a considerable share of attention, and a map was given showing in color the deposits of magnetic, specular, and limonite ores, and limestone of the York and Spartanburg districts.

In the line of purely physical local geology, perhaps the most interesting part of the report lies in his discussion of the possible subsidence of the coast going on at the present time. He showed, to his own satisfaction at least, that the presence of stumps of trees below and partly below the present sea level was due to the gradual undermining of sand and mud flats on which they grew and the consequent settling of the stumps, retained in an upright position by their wide-spreading roots, and not to a subsidence of the coast, as taught by Lyell, Bartram, and later by Lieber and Cook.[a] The origin and nature of the soils, the mining and preparation of fertilizers, including lime burning, the washing and milling of gold ores, and kindred subjects, were touched upon. Many soil and fertilizer analyses were given, the latter and their discussion being largely by Prof. C. U. Shepard, then professor of chemistry in the Medical College of the State, at Charleston. The fossils were identified by Conrad and Gibbs.

It is but natural that a considerable portion of the work should be given up to a discussion and description of the Tertiary deposits, which cover more than half the area of the State. Concerning these he recapitulated as follows:

1. That they are situated in a vast depression in the Cretaceous rocks, which, however, are only visible on the east and northeast.

2. That the Eocene consists of three well-defined groups: (1) The Buhr-stone formation, composed of thick beds of sand, gravel, grit, clay, and buhr-stone, amounting to at least 400 feet in thickness and underlying the calcareous beds. Its upper portions are characterized by beds abounding in silicified shells, for the most part identical with the Claiborne fossils. As these are littoral shells, they probably occupied the coast while the Santee beds were forming in deep water. The materials of which this formation is composed are the ruins of the granitic and metamorphic rocks of the upper districts, which may often be traced to their origin. (2) The Santee beds, consisting of thick beds of white limestone, marl, and greensand. These are best seen on the Santee, where, interstratified with the greensand, they dip gently toward the south. The coralline marl of Eutaw is found near the upper edge of these beds. (3) The Ashley and Cooper beds, which are the newest Eocene beds of the State. The marl of these is characterized by its dark gray color and granular texture, while the remains of fishes and mammalia give its fossil remains a peculiar character and leave no doubt of the position assigned it—at the top of the Eocene series. These, together with the Santee beds, must amount at least to a thickness of 600 or 700 feet.

3. That although these strata contain throughout characteristic Eocene fossils, yet they also inclose some Cretaceous forms.

4. That the Middle Tertiary of the State, composed of beds of sand and marl, highly fossiliferous, is scattered, like similar beds in other places, over the Eocene and Cretaceous formations in isolated patches. That the proportion of recent species increases toward the south, and that the extinction of species seems to proceed in that direction, as is proved by the fact that the recent forms, which are also fossil, belong to a more southern fauna, there being but one or two exceptions.

5. That in South Carolina the proportion of recent species in this formation amounts to 40 per cent. I have, therefore, referred it to the older Pliocene.

6. That the post-Pliocene is confined to a belt along the coast of about 8 or 9 miles in breadth. The fossils are nearly all referable to living species now inhabiting the coast; a few, however, belong to the fauna of Florida and the West Indies. An elevation of the coast has taken place since the deposition of these beds, which, it is probable, has given the rivers of the Atlantic slope a western tendency.

[a] Tuomey's view was upheld by Prof. N. S. Shaler as recently as 1870. Proceedings of the Boston Society of Natural History, XIII, p. 228.

7. That the submerged stumps of trees found below the level of high tide along the coast are not the result of subsidence, properly so called, but must be referred to the encroachment of the sea upon the land and to the peculiar character of the deposits in which they grew.

8. That the almost entire absence of fluviatile shells in the recent and Tertiary deposits is mainly due to two facts: (1) That there is a considerable space between the line of brackish and salt water, where neither fluviatile nor marine forms can exist; (2) that the streams have not transporting power sufficient to bring down fresh-water shells. So long as these circumstances exist, there can be no mixture of fluviatile and marine shells.

Tuomey's Survey of Alabama, 1848-50.

Prior to 1848 the professor of geology in the State University of Alabama had been required to spend a portion of his time, not exceeding four months of each year, in making geological explorations in the State. In January, 1848, the general assembly, in recognition of the utility of this work, passed a resolution appointing Michael Tuomey, then holding this professorship, State geologist, and requiring him to make a report to the general assembly at each of its biennial sessions. Thus simply was inaugurated the first systematic geological survey of the State.

Under this law, Tuomey's First Biennial Report, in form of an octavo volume of 176 pages and a colored geological map of the entire State, appeared in 1850. In this the rocks of the State were divided into those of (1) The Primary, (2) Metamorphic, (3) Silurian, (4) Carboniferous, (5) Cretaceous, and (6) Tertiary systems, the last named being represented, so far as then known, only by the Eocene. Much of the report was taken up with economical considerations, particular attention being paid to coal and iron.

The second report of this survey appeared under the editorship of J. W. Mallet, the publication having been delayed through the procrastination of the Public Printer and Professor Tuomey's death, which occurred in March, 1857.

Tuomey recognized on Marble Creek in Limestone County a blue limestone which was a continuation of the Silurian rocks in Tennessee. The Devonian rocks were represented by black slate found on the principal streams flowing from the north into the Tennessee between Flint River in Madison and Shoal Creek in Lauderdale County. He regarded the divisions of the carboniferous made by Troost as sufficiently characteristic in north Alabama to be retained.

The clastic material—that is, the loosely consolidated sands and gravels—which he mapped as extending across the middle of the State and north of the verge of the Cretaceous beds, and colored as post-Tertiary, were referred to as belonging to the drift, although having little resemblance to that of the north. "If the southern drift be at all connected with that of the north," he wrote, "it may be explained by supposing that the northern glaciers suddenly melted, and that the water thus liberated in immense volume took a southern direction, carrying with it the débris torn from the surface over which it passed until it met the Tertiary sea, upon the shores of which its burden was deposited." This theory, he felt, would sufficiently account for that enormously long ridge of drift extending parallel with the Atlantic coast, for the moment the current entered the Tertiary sea its velocity would be checked and the greater part of the transported detritus deposited. The reader will here recognize an old idea, but slightly modified.

Commenting on the fact that these beds contain no fossils, he wrote:

The only way by which I can account for this * * * is by supposing that, before the drift period, the bottom of this sea had been elevated and converted into dry land, and that at the commencement of the drift period a depression of the land took place; that the time between the influx of the sea and the deposition of the drift was too short for marine animals even to have commenced a colonization, and that the land was again elevated into its present position and subjected to long-continued denudation, which produced its present configuration; that after this elevation the rivers excavated their present channels.

Tuomey was assisted in this work by Oscar M. Lieber, geologist, and J. W. Mallet, chemist.

The withdrawal of Tuomey from the field in South Carolina incidental to his removal to Alabama left the position of State geologist vacant until the appointment of Lieber, in 1855. In the meantime F. S. Holmes, working privately, gave in the American Journal of Science for 1849 a brief paper on the geology of the vicinity of Charleston, which may be noted here, with the preliminary remark that this was Doctor Holmes's first venture in the geological field. In this paper attention was called to the fact that the city of Charleston was built upon geological formations supposed to be identical in age and in other respects similar to those upon which London and Paris are located, i. e., upon the Eocene. The adjacent sea islands he thought to have been formed through the action of the ground swell of the ocean and the streams flowing down from the interior during the time when the land was gradually emerging from the sea.

F. S. Holmes on the Geology of Charleston and Vicinity, 1849.

He agreed with Tuomey in taking exception to the then generally received opinion that the sea was advancing upon these shores, having been led by his own observations to the conclusion "that if the ocean does wash off portions of the shore at one exposed point it deposits the same at no great distance upon another." The supposed indications of subsidence, such as the stumps and roots of trees now below the level of high tide, he accounted for on the supposition that outer sand barriers, which had prevented the ingress of salt waters, were gradually removed, allowing the waves to wash away the fine silt and mud between the roots of the trees, thus permitting them to sink into it and become embedded. This, it will be noted, was essentially the view advanced by Tuomey.

Holmes classified the formations met with as post-Pliocene, Miocene, and Eocene, the post-Pliocene, where observed, resting directly upon the Eocene. This he would account for on the supposition that during the deposition of the post-Pliocene the Miocene areas were above water, or had been denuded of their post-Pliocene covering previous to the deposition of the alluvial or diluvial sands and clays.

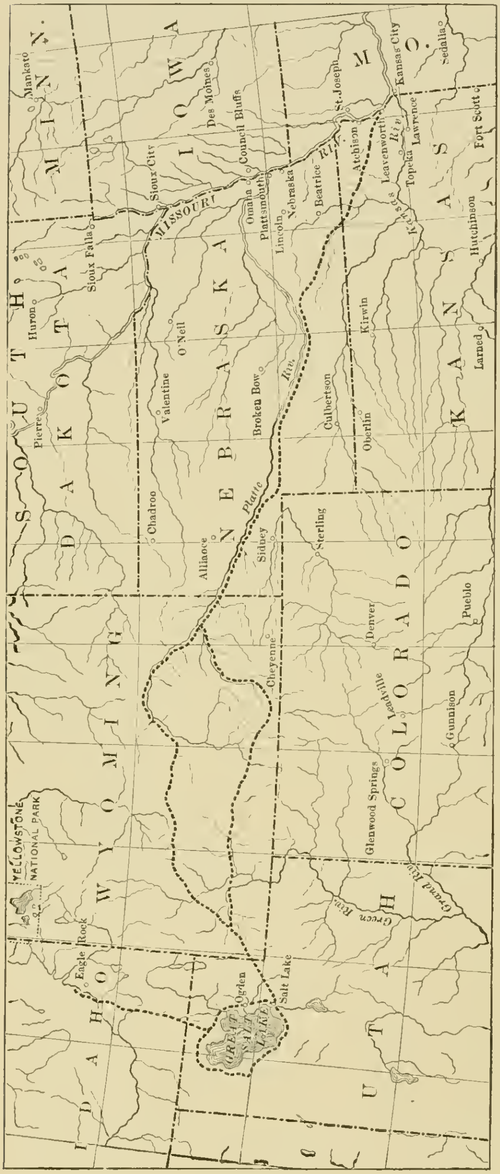


FIG. 41.—Map showing Stansbury's routes in 1849–50.

Captain Stansbury's Explorations in Utah, 1849.

In 1849 Capt. Howard Stansbury, of the corps of topographical engineers, acting under authority of the War Department, explored the valley of Great Salt Lake. The expedition left Fort Leavenworth May 31, 1849, taking a northwest direction and striking the Platte at Fort Kearney, proceeding thence along this and the North Fork to the Sweetwater, and thence across South Pass to Fort Bridger and Salt Lake City. The return trip was made by a more southerly route, through Bridger Pass, striking the old route again at Fort Laramie, and thence back to Fort Leavenworth, the latter point being reached the 6th of November, 1850.

No geologist accompanied this expedition, and a small series of rocks and fossils which were collected were reported upon by James Hall. Forms belonging to the Cretaceous, Carboniferous, and Silurian or Devonian ages were identified.

D. D. Owen's Work in the Chippewa District and in Wisconsin, Iowa, and Minnesota, 1847–1851.

In 1847 Doctor Owen was again employed by the Treasury Department, under immediate supervision of General Land Commissioner R. M. Young, to make surveys in the Chippewa district of Wisconsin and the northern part of Iowa. The region lies between 43° and 47° north latitude and 89° and 94° longitude west of Greenwich, embracing about 46,000 square miles and, as shown on the map (fig. 45), comprising that portion of the country "lying chiefly east of the upper Mississippi above Lake Pepin and extending north to Lake Superior." Incidentally, there was included a portion of Iowa "stretching north from the northern boundary of the geological survey of 1839 as far as the St. Peters River, and also a tract of country north of the Wisconsin River."

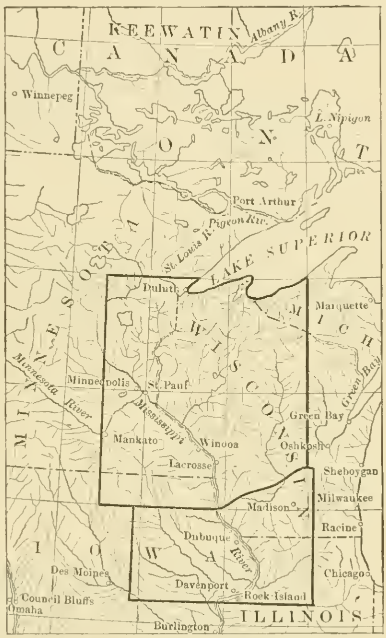


Fig. 45.—Map of areas surveyed by D. D. Owen in Iowa, Wisconsin, and Illinois in 1839, and the Chippewa Land District in 1847.

As in the previous survey, the time was limited, only the summer and autumn of 1847 being devoted to field work, the report, printed in form of Senate Document No. 57 of the first session Thirtieth Congress, bearing the date of April 23, 1848. It comprised 134 pages, with one geological map, 23 lithographic plates from drawings by Doctor Owen, and 13 colored plates of sections. Some of these last were beautiful combinations of sections and perspective landscapes, and give at a glance a general idea of the surface features as well as the character and dip of the underlying rock masses, such as is rarely excelled. (See Plate 19, from his section 5.) Even when one considers that, as Owen states, the working time of the members of his corps was from twelve to fifteen hours a day, still one wonders that so much was accomplished and presented in such good form. Though a detailed geological survey was made of only about thirty townships west of the fourth principal meridian on Black River and sixty townships on the St. Croix, sufficient data was obtained to enable him to lay down with approximate accuracy the general bearing and area of the principal formations of over two-thirds the area above noted. He showed, also, that both the upper and lower magnesian limestone, were lead-bearing, and that there existed in Wisconsin two, if not three, trap ridges similar to those of Michigan, and which, like the last, "hold out a prospect of productiveness."

In this report, too, he first announced that the upper Mississippi country north of the Wisconsin River was based upon magnesian limestones which were older than the lowest formations of the valley of

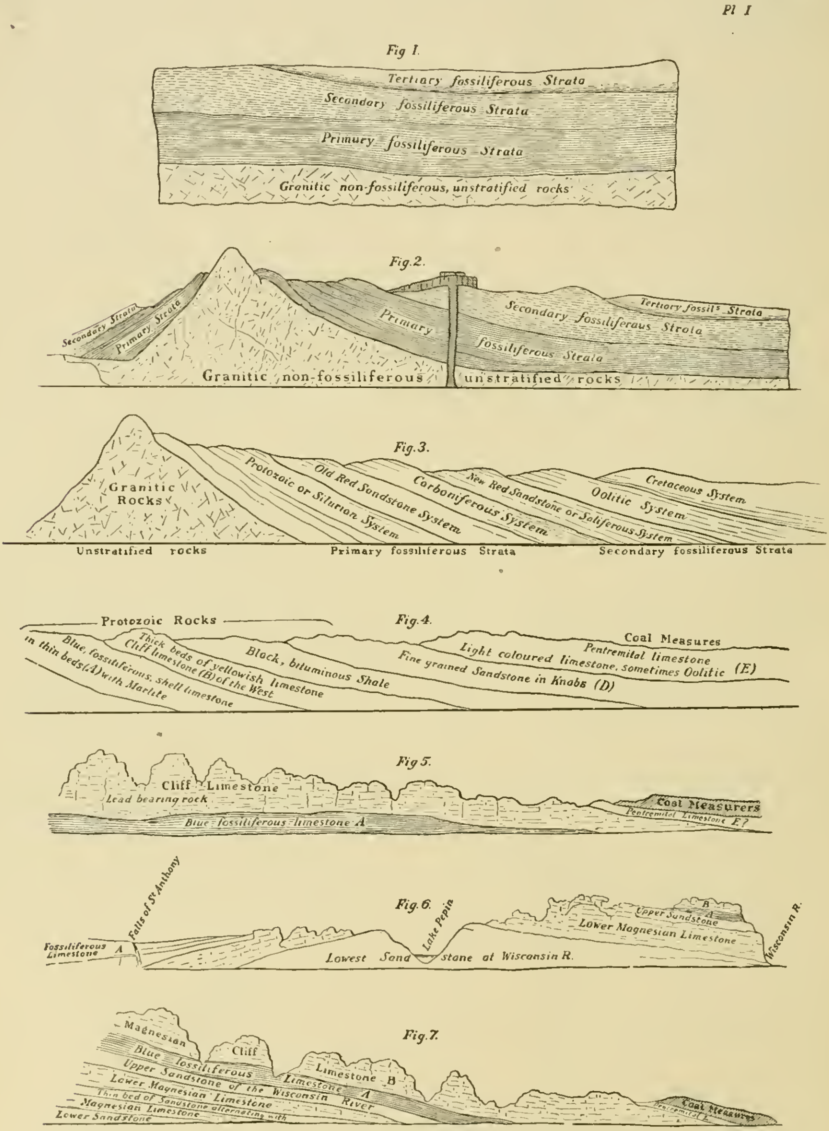


FIG. 46.—Owen's geological sections.

the Ohio, a portion of them being contemporaneous with the Calciferous group and Potsdam sandstone of New York. He noted also that the Falls of St. Anthony are receding and were probably at one time at a point near Fort Snelling.

Concerning the red sandstones of the south and west shores of Lake Superior, he wrote: "There is strong presumptive evidence that they were deposited subsequently to the Carboniferous era." His evidence, though, was admittedly weak and later was acknowledged to be wholly misleading and insufficient.

This preliminary reconnaissance ended, Owen was instructed to make a survey of the Northwest Territory, embracing chiefly Wisconsin, Iowa, and portions of Minnesota. The manuscript of his final report of this work was submitted in 1851 and published under date of 1852 in the form of a quarto volume of 628 pages of text, with 15 plates of fossils, 19 folding sections, and a geological map. The illustrations of the fossil remains are of particular interest, being medal-ruled on steel, the first of their kind produced in America.

Owen was assisted in this survey by Doctors Shumard and Litton, of St. Louis; Dr. John Evans and F. B. Meek, of Owensboro, Kentucky; Col. C. Whittlesey, of Cleveland, Ohio; and Messrs. B. C. Macy, Henry Pratton, George Warren, and John Beale, of New Harmony, Indiana.

To Doctor Leidy fell the work of describing the vertebrate fossils collected by Doctor Evans in the Bad Lands of Nebraska. Among these fossils was the now well-known Oreodon, an animal with grinding teeth like the elk and canines like those of omnivorous thick-skinned animals, belonging, as was thought, to "a race which lived both on flesh and vegetables and yet chewed the cud like our four-footed grazers."

This work was the first systematic account published of the Bad Lands fossils. The first mammalian remains to be described from this region, it should, however, be noted, consisted of fragments of the jaw of an enormous pachyderm, which were described by Dr. H. A. Prout, of St. Louis, in the American Journal of Science for 1847.

Owen regarded the gypsum deposits of Dubuque as due to original deposition at the bottom of an ocean, the sulphate of lime having probably been derived during the formation of the rocks and from submarine sources. This view is somewhat remarkable when it is recalled that of the total lime salts in solution in sea water, 90 per cent occur in the form of sulphates and would be deposited as gypsum during the ordinary processes of evaporation.

His views on the origin of the drift were in accordance with those of the leading authorities of his day. The large bowlders he regarded as having been deposited by floating ice and drifted by currents from the north while the country was depressed. The opinion which he had previously expressed (in 1848) concerning the age of the Lake Superior sandstones was in this final report retracted, and he relegated them, on stratigraphic evidences only, to the Potsdam formations, which is in accordance with the prevailing opinion of to-day.

Of greater importance was the fact, first announced in his report for 1847–48, but here brought out in detail, that underlying his lower magnesian limestone (Chazy) there were at least six different trilobite-bearing beds, separated by from 10 to 150 feet of intervening strata. Previous to this no remains of this nature had been reported from any American strata older than the Canadian period of the Lower Silurian. These trilobite-bearing strata, it should be noted, were found resting immediately upon the primal rocks and hence formed the true base of the zoological series in the Mississippi Valley.

On the title page of this volume appeared the cut of the horizontally jointed trap of Lake Superior that has long done duty in the text-books of Le Conte and others (see fig. 47).

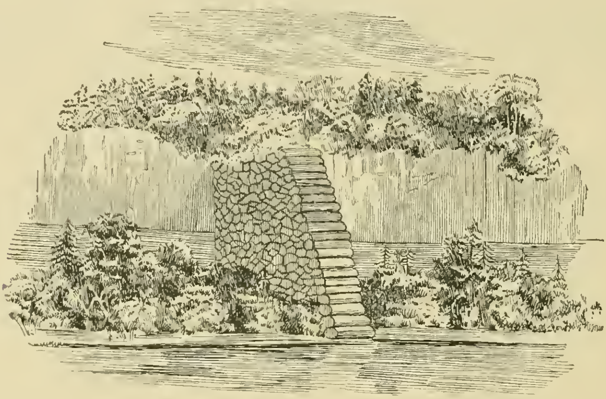


FIG. 47.—Trap dikes on Lake Superior. (After D. D. Owen.)

Work of C. T. Jackson in Michigan, 1847.

In accordance with an act of Congress approved March 1, 1847, Dr. C. T. Jackson was appointed by the Hon. R. J. Walker, then Secretary of the Treasury, to make a geological survey of that portion of Michigan lying south of Lake Superior and north and northwest of Lake Michigan. As in previous operations of like nature by Owen, the object of this survey was to ascertain which of the lands should be classed as mining lands and which agricultural. Jackson spent two seasons in the prosecution of this work and then resigned, for reasons which seem to have been in part personal and in part political, the completion of the work being confided to his assistants, J. W. Foster and J. D. Whitney.

Jackson's report was published as House Document No. 5, Thirty-first Congress, first session, 1849. It comprised upward of 560 pages, with 19 plates, geological maps of Keweenaw Point and Isle Royal, and three sections of mines. The eruptive rocks of Keweenaw Point were described as having been intruded through linear caverns or fractures in the superincumbent rock which they had frequently overflowed, so as to rest unconformably on their strata. Here is again recognized the possibility of fissure eruptions as distinctive from the crater eruptions of modern volcanoes.

The red sandstones of Lake Superior were erroneously regarded as belonging to the New Red series, the opinion being based upon a tract of limestone carrying the fossil *Pentamerus oblongus*, which was found in the midst of the sandstone near Anse.

Jackson, it is well to note, was opposed to the principle of the reservation of mineral lands by the General Government. He wrote:

> It may be useful to the public to cause geological and mineralogical surveys to be made for their information, but I am satisfied that the reservation of mineral lands is a great evil to the country, and that the Government never can derive revenue from such sources, while the restriction most seriously embarrasses the settlement of newly acquired territory. The above remarks are applicable to the whole copper region, and I would not advise the reservation of any part of it as mineral land.

Jackson's chief assistants were J. D. Whitney and J. W. Foster, already noted, Dr. John Locke, and Dr. Wolcott Gibbs.

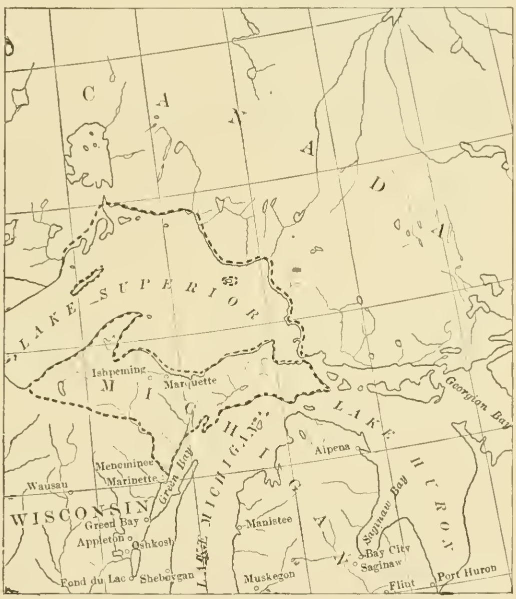


Fig. 48.—Map showing area surveyed by Jackson, and Foster and Whitney, 1847–49.

Agassiz's Physical Characters of Lake Superior, 1848.

In 1848, while occupying the chair of zoology and geology at Harvard University, Louis Agassiz, in company with Jules Marcou and a party of students, undertook an exploration of the Lake Superior region, the results of which were published in 1850, under the caption of Lake Superior; its Physical Character, Vegetation and Animals, compared with those of other and similar regions. Marcou would have us believe that this volume marked an epoch in natural history publications in America, this mainly on account of the superior style of its illustrations. Certainly there was much to justify the claim.

The country was nearly everywhere roadless, and transportation by water possible only through the aid of birch-bark canoes. As might be expected, the purely geological observations were of little value, excepting so far as they related to glaciation. Agassiz argued that the form of the lake was due to "a series of injections of trap dikes of different characters, traversing the older rocks in various directions." He found six systems of these dikes, to the trend of which the various lake shores in a general way conformed. The relationship of the various copper deposits he attempted to explain on the somewhat remarkable, as well as ingenious, assumption that the material had been poured out in a melted condition, and, cooling quickly, remained in the native state, offering to the agencies of change a relatively small surface exposed in proportion to its mass. At a distance from the main mass, where the ejections were small with relatively large surfaces exposed, they became more or less completely changed into oxides, sulphides, carbonates, etc. The reader need scarcely be reminded that authorities to-day hold quite a different view, and regard the copper as having been precipitated by reduction to a native state from salts held in permeating solutions.

Naturally, Agassiz's views, as here set forth on the glacial phenomena of the region, are of paramount interest. He argued that the drift of all northeast America and northwest Europe was contemporaneous and due to a general ice sheet. Through a repetition of many of his former arguments he showed that a current of water sufficiently powerful to transport the large blocks found would have swept practically over the entire globe, and not have stopped abruptly, as did the drift, after reaching latitude 39° north. This limit of distribution of the bowlders to the northern latitudes also indicated to his mind that the matter of climate was an important factor. Water-transported material, he further argued, would not cause straight furrows and scratches, and the theory that such might be due to drifting icebergs was rejected on the ground that existing bergs were insufficient, and to produce such as were would necessitate a period of cold sufficient for his hypothetical polar ice cap. He pointed out that the northern erratics were rounded and widespread; that the highest hills were scratched and polished to their summits, while to the southward the mountain tops had protruded above the ice sheets and supplied the glaciers with their load of angular bowlders. He also called attention to the absence of marine or fresh water shells from the glacial (ground moraine) deposits, showing it was not subaqueous. Referring to the stratified deposits overlying the drift, he wrote:

> The various heights at which these stratified deposits occur above the level of the sea show plainly that since their accumulation the mainland has been lifted above the ocean at different rates in different parts of the country.

And, further:

> It must be at once obvious that the various kinds of loose materials all over the northern hemisphere have been accumulated, not only under different circumstances, but during long-continued subsequent distinct periods. To the first—or ice period—belong all phenomena connected with the transportation of erratic bowlders, polishing, scratching, etc., and during which the land stood at a higher level. To the second belong the stratified drift, such as indicate a depression of the continent.

Louis Agassiz was born in Motier, Switzerland, in 1807, and came into world-wide notoriety through his works on fossil fishes and his enthusiastic exploitation of the glacial discoveries of Hugi, Venetz, and Charpentier, while in Neuchatel. He came to America to better his finances in 1846, and after delivering courses of lectures before the Lowell Institute in Boston and in other of the eastern cities, accepted, in 1847, the professorship of geology and zoology in Harvard University. Agassiz was not, however, a geologist, and his service to this branch of science after coming to America was more as a teacher and through arousing public interest than by research. His enthusiasm was too great, his staying power too slight; he was too prone to jump at conclusions to make a good geologist, as shown in his hasty assumption that the bowlders of decomposition found by him in Brazil were drift bowlders and indicative of a former glacial period in that latitude.

Sketch of Agassiz.

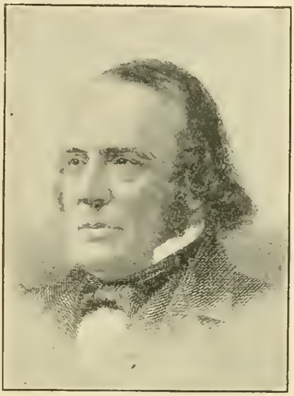


Fig. 49.—Louis Agassiz.

The work begun by Jackson in Michigan and under direction of the General Land Office in 1847 was, as already shown, continued by Messrs. J. W. Foster and J. D. Whitney. Their reports were issued in octavo form, Vol. I, on the copper lands, constituting House Executive Document No. 69, first session, Thirty-first Congress, 1850, and comprising 224 pages, with 12 plates and a facsimile of a map of Lake Superior made by the Jesuit missionaries in 1671. Vol. II, or Part 2, on the iron region, appeared as Senate Executive Document No. 4, special session, March, 1851. This comprised, all told, 406 pages, with 33 plates. A colored geological map of the area surveyed accompanied the report. Some of the more important items noted are as below:

Foster and Whitney's Work in Michigan, 1849-51.

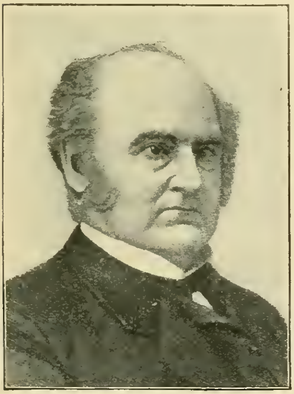


Fig. 50.—John Wells Foster.

They stated that Lake Superior occupies an immense depression which has been for the most part excavated out of the soft sandstone of the Potsdam age. The configuration of that portion of the lake lying west of longitude 88° was deemed as due to two axes of elevation extending in parallel lines from the northeast to the southwest, which upraised the sandstone, causing it to form a synclinal valley.

This, it will be noted, is radically different from the idea put forward by Agassiz.

The conglomerate composed of rounded fragments of jaspery rock, so abundant throughout the copper region of the south shore of the lake, they regarded as a friction conglomerate, testifying to the "intensity of the force with which the eruptive rocks have been propelled from the interior through the earth's crust," the detritus having been redistributed by the waters, following in this the teachings of Von Buch. Their graphic account of the conditions under which it was supposed to have been formed is worthy of being reproduced entire:

We may suppose that at one time all of this district (i. e., the copper district) formed a part of the bed of the primeval ocean. Adopting the theory of a cooling globe, we may further suppose that the waters were in a heated condition and differed essentially in chemical composition from those of the present oceans. The earth's crust was intersected by numerous powerful fissures, and the communication between the exterior and interior was unobstructed. Volcanic phenomena were much more frequent and exerted on a grander scale. Each volcanic paroxysm would give rise to powerful currents and agitations of the water, and their abrading action in detaching portions of the preexisting rocks, and depositing them in beds and layers on the floor of the ocean, would operate with greater intensity than at the present time. We can trace the remains of one volcanic fissure extending from the head of Keweenaw Point, in a southwesterly direction, to the western limits of the district, and of another, in a parallel direction, from the head of Neepigon Bay to the western limits of Isle Royale. Along the lines of these fissures existed numerous volcanic vents, like those observed at this day in Peru, Guatemala, and Java, which were characterized by periods of activity and repose. From these vents were poured forth numerous sheets of trap, which flowed over the sands and clays then in the progress of accumulation. During the throes and convulsions of the mass portions of rock would become detached and rounded simply by the effects of attrition, and jets of melted matter be projected as volcanic bombs through the air or water, which, on cooling, would assume spheroidal forms; while other portions of the rock, in a state of minute mechanical division, would be ejected in the form of ashes and sand, which, mingling with the water, would be deposited as the oscillations subsided among the sands and pebbles at the bottom of the sea. During the whole of this period of volcanic activity the sands which now form the base of the Silurian system were in the progress of accumulation and became mingled with these igneous products. The level of the sea, as evidenced by the ripple marks, was subject to repeated alterations; sometimes it rose so shoal that the marks of the rippling waves were impressed on the sands, at others it sank to unfathomable depths.

In the process of consolidation the rocks became traversed by numerous fissures, and the water, charged with lime, was forced in like jets of steam, filling them with materials different from the inclosing mass. In this way the pores in the conglomerate and the vesicles of the amygdaloid were filled.

The formation of the copper and silver ores they regarded as due probably to electro-chemical agencies. To quote their own words:

The existence of two metals side by side, like copper and silver, each chemically pure and capable of being alloyed in any proportions; the accumulation of the latter near the cross courses or at the junction of two mineral planes; the changes in the metallic contents of lodes in their passage through different rocks, and the parallel arrangement of the earthy gangues, all seem to indicate the existence of electrical currents during the period of their formation.

Concerning the origin of the drift and the phenomena of the groovings and striations of the rocks in the regions, they were still somewhat in the dark. The position of bowlders resting on stratified deposits of sand and clay was regarded as antagonistic to the theory of a general ice cap similar to that of the circumpolar region. It was thought that such might rather have been transported by floating ice (not icebergs) in the same manner that bowlders are even now each spring transported from the borders of the northern lakes and rivers and dispersed over the adjacent swamps and lowlands.

The slates of the region were looked upon as probably originally laid down as volcanic ashes and subsequently consolidated a by no means improbable theory. The specular and magnetic iron ores they, strangely enough, regarded as—

a purely igneous product, in some instances poured out, but in others sublimated, from the interior of the earth. We may conceive that the various rocks of the Azoic series were originally deposited in a nearly horizontal position. During the deposition of these strata, at various intervals sheets of plastic matter were poured forth from below and spread out upon the surface of the pre-existing strata. During this period the interior of the earth was the source of constant emanations of iron, which appeared at the surface in the form of a plastic mass in combination with oxygen, or rose in metallic vapors or as a sublimate, perhaps as a chloride; in the one case it covered over the surface like a lava sheet, in the other it was absorbed into the adjacent rocks or diffused through the strata in the process of formation.

The igneous rocks they classified as dolerite, anamesite, and basalt. The sandstone, which occupies almost exclusively the bed of Lake Superior and which occurs in isolated patches along the shore and on the islands, they rightly classed as Potsdam, differing in this respect with Jackson, who considered it as New Red, and from Locke and others, who thought it to be the equivalent of the Old Red or Devonian sandstone of Europe.

The work on the Paleozoic rocks, as given in Part II of these reports, was done by James Hall, of New York. The limestones first seen upon St. Marys River, Hall regarded as identical with the Chazy, Bird's-eye, Black River, and Trenton limestones of New York. The Cliff limestone of Owen he designated as the Galena limestone, which he erroneously regarded as a distinct member of the Lower Silurian system, not recognized in the East.

Hall's Report on Lake Superior Rocks.

In his chapter on the parallelism of the Paleozoic deposits of the United States and Europe, Hall called attention to the fact that—

The simplest principles of elementary geology teach us that sedimentary beds, having the same thickness and same lithographical characters, can not have spread over an area so wide as that now included between the European and American continents. All sedimentary deposits must vary in character at remote points, as the physical conditions of the ocean can not be presumed to have remained the same over a wide extent of surface. Under such circumstances, absolute parallelism is not to be sought for or expected. Calcareous deposits, as would naturally be supposed, have been found to be more persistent and more uniform in the character of their fossil contents; but these, over some portion of their extent, have often been invaded by argillaceous and arenaceous sediments, and the fauna is found to be in a greater or less degree influenced by such circumstances.

The following table was given, showing the subdivisions of the Paleozoic series in New York:

1. Potsdam sandstone.	
2. Calciferous sandstone.	
Upper sandstone of Wisconsin and Minnesota similar to the Potsdam sandstone.	
3. Chazy limestone.	
4. Bird's-eye and Black River limestone.	
5. Trenton limestone.	
Galena or lead-bearing limestone of Wisconsin, Iowa, and Illinois not recognized at the East.	
6. Utica slate.	Included in the Hudson River group.
7. Hudson River shales.	
8. Gray sandstone.	
9. Oneida conglomerate.	
10. Medina sandstone.	
11. Clinton group.	
12. Niagara group, coralline limestone of Schoharie.	
13. Onondaga salt group.	
14. Tentaculite or water limestone.	Lower Helderberg group.
15. Pentamerus limestone.	
16. Delthyris shaly limestone.	
17. Encrinal limestone.	
18. Upper Pentamerus limestone.	
19. Oriskany sandstone.	
20. Cauda-galli grit.	Upper Helderberg group.
21. Schoharie grit.	
22. Onondaga limestone.	
23. Corniferous limestone.	
24. Marcellus shale.	Hamilton group.
25. Hamilton group.	
26. Tully limestone.	
27. Genesee slate.	
28. Portage group.	
29. Chemung group.	
30. Sandstone and shale of the Catskill Mountains.	
31. Gray and yellow sandstone.	
32. Great Carboniferous limestone.	

The following was given to show the equivalency of the Cliff limestone with the New York group:

CLIFF LIMESTONE.

5.	Trenton limestone.	Wanting at the east and southeast.
	Galena limestone.	
6–8.	Hudson River group.	
9.	Oneida conglomerate.	Wanting at the west.
10.	Medina sandstone.	
11.	Clinton group.	The Niagara and the calcareous portion of the Clinton.
12.	Niagara group.	
13.	Onondaga salt group.	Wanting west of Lake Michigan.
14.	Tentaculite limestone.	Wanting in the States north of the Ohio River.
15.	Pentamerus limestone.	
16.	Delthyris shaly limestone.	
17.	Encrinal limestone.	
18.	Upper Pentamerus limestone.	
19.	Oriskany sandstone.	Wanting at the west and southwest.
20.	Cauda-galli grit.	
21.	Schoharie grit.	
22.	Onondago limestone.	
23.	Corniferous limestone.	

The following table was intended to show the equivalency of the New York forms with those of Europe:

Llandeilo flags.	? Trenton limestone, in part. ? Utica slate.
Caradoc sandstone.	Hudson River group. Clinton group, in part.
Wenlock series.	Clinton group, in part. Niagara group. Lower Helderberg limestones.
Ludlow series and Devonian system.	Upper Helderberg limestones. Hamilton group. Chemung group. Red sandstone and shale of Catskill Mountains.

The Chazy, Bird's-eye, and Black River limestones, the Onondaga salt group and the Oriskany sandstone he regarded as having no representation among British strata.

Commenting on the proportion of species represented by European authorities as passing from Devonian to Carboniferous, he wrote:

It is so enormously great that we find no parallel to it in any preceding period. * * * From all these facts there seems to be but one conclusion, and that is, in the British Isles particularly, either there are remarkable exceptions to the general law in the continuation of species from one to another or that there is no foundation for a distinction between the Devonian and Carboniferous systems.

Further on he wrote:

We can not avoid the conclusion that, if we adopt the Devonian system with the limits suggested by foreign writers, we must drop forever the attempt to recognize the Ludlow division of the Silurian system.

The drift phenomena of the region studied by Foster and Whitney were described by E. Desor, who divided the deposits into four classes, as follows, beginning with the lowermost:

Desor on the Drift, 1852.

"1. A layer of coarse, pebbly loam called "coarse drift."

2. Clay resting either on the coarse drift or directly on the rock.

3. A deposit of sand, gravel, and pebbles, irregularly stratified, resting upon the clay or the bed rock.

4. Isolated bowlders scattered over the whole region.

While disclaiming any intention of giving a general theory for the causes and origin of the drift, he argued that the phenomena he described indicated neither paroxysmal agencies nor the operation of any single cause, however long continued. "They disclose a long series of events which have resulted from causes highly diversified, and as yet imperfectly known. Three periods are recognized in the history of the drift of the Lake Superior region: (1) 'The period of the grooving and polishing of the rocks,' which 'must be considered as the dawning of the drift epoch;' (2) a period of comparative quiescence, extending over a long period of time and during which the stratum of red clay was deposited. This is the second era of the drift. (3) The overlying stratum of sand and gravel presumably formed by water, but at higher levels than the clay and indicating a still further depression of the land. This period characterized by intervals of agitation and repose. He considered that earthquake waves, according to H. D. Rogers's ingenious theory, *might* be responsible in part for these."

The transportation of the bowlders, he thought, took place at the close of the drift epoch.

In another article in the American Journal of Science for the same year (1852), concerning the post-Pliocene of the Southern States and its relation to the Laurentian of the North and the deposits of the Mississippi Valley, Desor attempted to account for the large bowlders in the drift of Long Island by means of ice rafts. The bowlders in the post-Pliocene of the Southern States were doubtfully referred to water action only.

Desor, according to Marcou, was a German, who had come to America as private secretary to Agassiz, and whatever views he may have had on glaciation or other scientific subjects may be regarded as mainly absorbed rather than learned from observation. Through becoming over-presumptuous he had a falling out with his master, which resulted in his discharge in 1848 and return to Germany in 1852, passing thus beyond the limits of our field of study.

J. D. Dana, as already noted, served as geologist in the United States exploring expedition under Captain Wilkes, during the years 1838-42. The results of his observations during this time are embodied in the tenth volume of the reports of the expedition, a royal octavo of 756 pages, with a folio atlas of 21 plates. Many of the conclusions given in this volume were first published in the columns of the American Journal of Science, and have already received attention.

Dana and the Wilkes Exploring Expedition.

One of the earliest results of Dana's work, as here chronicled, was the establishment of the principle that temperature influences the growth and distribution of corals. A claim to priority in this discovery was made by James P. Couthouy, and brought about a personal controversy somewhat bitter between the two authors. This has been alluded to elsewhere (p. 373).

The existence of harbors about the coral-bound reefs Dana attributed largely to the action of tidal and local marine currents, though the presence of fresh-water streams may have contributed toward the same end.

He rejected the then popular theory of the formation of coral reefs and atolls through the gradual subsidence of volcanoes, the crater corresponding to the lagoon and the rim to the belt of land, though believing that, beyond question, a subsidence had taken place throughout a large part of the Pacific, and hence that subsidence must form a part of any true theory of the origin of the reefs.

He believed that the atoll once formed a fringing reef about a high island. This, as the island subsided, became a barrier reef, which continued its growth while the land slowly disappeared. The area of waters within finally contained the last sinking peak, which itself finally disappeared, leaving only the barrier at the surface and an islet or two of coral in the inclosed lagoon.

These were essentially the views put forward independently by Darwin. The recent work of the younger Agassiz has shown them to be not wholly correct.

From the actual extent of the present coral reefs and islands Dana inferred that the whole amount of high land lost to the Pacific by this subsidence was at least 50,000 square miles, probably much greater, though he would not go so far as to conclude that a continent once occupied the place of the present ocean, or indeed of a portion of it.

In the discussion of the Hawaiian volcanoes it was noted that no apparent connection existed, so far as indicated by the phenomena of eruption, between Mount Loa and Kilauea, 16 miles distant and more than 10,000 feet lower. It was therefore concluded that the two conduits, which he assumed were once connected by a fissure, had become isolated through the solidifying of the lava between them, each conduit being possibly a separate branch of some deep-seated channel.

The wide difference in the height of the columns of lava in two volcanoes so near together as those noted above caused him also to doubt the statement so commonly made by writers of that day to the effect that volcanoes were safety valves.

Assuredly, if, while Kilauea is open on the flanks of Mount Loa — a vast gulf 3½ miles in diameter — lavas still rise and are poured out, Kilauea is no safety valve even to the area covered by this single mountain alone.

The conclusions based upon the study of these Hawaiian volcanoes were to the effect that:

1. The majority of the Pacific volcanic summits were formed from successive eruptions of molten rock, alternating sometimes with cinder or fragmentary ejections.

2. That the eruptions are, in general, the result of a rising or ascent of the lavas, owing to the inflation by heat of such vaporizable substances as sulphur and water, the overflow or lateral outbreak taking place in consequence of the increased pressure from gravity and from the elasticity of the confined vapors, the contraction of the earth's surface being no more necessary for an eruption than the contraction of the sides of a pot of water to make it boil.

He concluded further that volcanic action usually proceeded from fresh water gaining access to a branch belonging to some particular outlet or vent, and not to a common channel at greater depth. The lack of sympathetic action between two neighboring vents was thus explained on the ground that the union of their channels "took place far below the level to which the waters that ordinarily feed the fires gain access."

To the elevation theories of volcanic craters advocated by Von Buch he took exception, as he did also to the theory of Bischoff, who appealed to the internal igneous fluids for the source of volcanic action.

The highly feldspathic, coarsely crystalline, and solid centers of certain volcanic mountains, in contrast with the more vesicular and less dense outer portions, he rightly ascribed to slowness in cooling, the central mass being protected on all sides from the external air. Incidentally he discussed a problem which has become known to modern petrographers as that of magmatic differentiation. He argued that, given a large crater like that of Kilauea, the rise of the lavas through the center would be accompanied by a descending current along the side, though of less distinctness. The essential constituents of a rock, for example, being augite and feldspar, wherever the temperature of the liquid mass becomes sufficiently lowered, there the feldspar will commence to solidify or will slowly stiffen in the midst of the fluid material made up of the other ingredients. Under these conditions the ascending vapors would urge the feldspar upward much less freely than the more liquid part of the lava, for the latter would yield more readily to the inflating vapors and thus become lighter and rise to the surface. This process, going on throughout the whole progress of the cone, would keep the center feldspathic below a short distance from the summit. The residue from the feldspathic crystallization, consisting of ferruginous silicates, would be brought upward in the form of a frothy scoria which must on either side, in part, return to supply the place of the ascending current. On cooling, then, the more basaltic portions would constitute this exterior descending part. Thus, a feldspathic center and basaltic flanks would be the result of one and the same process. This feldspathic center, further, by being inclosed within a thick covering of rocks, would cool slowly, forming, perhaps, disseminated crystals in the earthy base, or, if cooling sufficiently slowly, a crystalline granular mass like granite or syenite.

He recognized the fact—

that particular rocks have no necessary relation to time, excepting so far as time is connected with a difference in the earth's temperature or climate and also in oceanic or atmospheric pressure, for, if the elements are at hand, it requires only different circumstances as regards pressure, heat, and slowness of cooling to form any igneous rock the world contains.

The date of the beginning of volcanic activity on the Hawaiian Islands he placed as far back as the early Carboniferous or Silurian epoch, and believed that: (1) There were as many separate rents in the region as there are now islands; (2) that each rent was widest in the southeast portion; (3) that the southernmost rent was the largest, and (4) that the order of extinction of the volcanoes was as follows:

1. Kauai.
2. Western Oahu.
3. Western Maui (Mount Eeka).
4. Eastern Oahu.
5. Northwestern Hawaii (Mount Kea).
6. Southeast Maui (Mount Kale-a-kala).
7. Southeast Hawaii (Mount Loa).

From the general arrangement of the islands in the Pacific and the study of the phenomena connected therewith the conclusion was reached that the Hawaiian group originated in a series of rents or ruptures seldom continued at the surface for a long distance, but frequently advancing successively, one after the other, causing the resultant islands to appear in the form of a curve rather than a straight line, and, further, it was announced that: (1) While straight ranges are of occasional occurrence, curved ranges are still more common; (2) that curvature may arise either from a gradual change of trend in the subordinate parts or from the position of these parts in a series; (3) that the same great chain may change its direction 60° or more, and consequently (4) the course of a mountain chain can be no evidence of its age. In this it will be observed he differed radically from Elie de Beaumont.

Dana noted further that the Pacific islands were arranged mainly in two systems of linear groups nearly at right angles with each other, the linear groups being based on a series of ruptures instead of a single uninterrupted fissure. The prevailing uniformity of trend of these fissures or ruptures he believed to be due both to the nature of the crust fractured and the direction of the fracturing forces. He accepted the doctrine of an earth cooled from a state of fusion, and regarded the influence of electric currents on the position of continents in process of formation as an established fact. An outer crust having once formed, the deep-seated crystallization would go on at a rate inconceivably slower, and circumstances would be favorable for a coarse crystallization of the material below and for the operation of electrical currents. The rupturing force he believed to be contraction caused by cooling. He argued that a cooling globe incrusted over by refrigeration while contraction was still going on beneath would, like a Prince Rupert's drop, be in a state of tension. Such a tension is bound to produce fractures and displacements, the direction of which would depend on rate of cooling in different parts and on the change in the earth's oblateness accompanying a diminution of its diameter. He concluded, from the absence of volcanoes in the interior of continents, that these portions of the globe cooled first and became solid; the intermediate portions cooling later and at a less rapid rate contracted most, since the crust was here thinnest. The oceanic areas would therefore be gradually subsiding and the tension increasing: moreover the tension, from its nature, would be exerted nearly horizontally. He inferred, therefore, that the subsiding oceans have produced the mountains of the continents, and that the oceanic and continental areas have never changed places, and saw no reason for appealing to an incomprehensible subterranean force for the uplifting of the mountain chains or the continents. Such may have been "only a result on the whole of the deepening of the ocean's bed. It is obvious * * * that the earth has reached its present condition by gradual progress from a state of prolonged igneous action through epochs of increasing quiet, interrupted by distant periods of violence, to the present time, when even the gentlest oscillations of the crust have almost ceased." These same ideas he had previously put forward in a paper in the American Journal of Science on the Origin of some of the Physical Features of the Earth's Crust, noted elsewhere.

In his discussion of the origin of the coal beds of New South Wales, Dana concluded—

that the layers of the coal series were probably deposited by fresh-waters during the different stages of annual floods and wider deluges occurring at more distant periods; that the subsidence, which may have been gradual during the coal deposits, finally submerged the whole.

Another important observation bearing on the same subject was made when writing on the geology of Luzon and its coal beds:

One of the interesting points about this lake (Laguna de Bay) is the fact that vast quantities of plants live on its surface and pass down the river into the bay, carrying along great numbers of fresh-water snails of different species. Here we have, therefore, fresh-water shells and vegetation which is not marine accumulating under salt water, for they sink after a while and must become buried in the mud of the bottom, along with the remains of marine life. This floating vegetation illustrates a theory with regard to the vegetation of the coal beds.

The gold excitement of California in 1848–49 drew attention to a region the geology of which was practically unknown. Fremont's expedition to California and Oregon in 1843–44 was not accompanied by a geologist, and the few fossils collected were described by James Hall. Some Notes on the California Gold Region, six pages only, were given by C. S. Lyman in the American Journal of Science for 1849, while J. D. Dana had touched upon the subject during his return overland after the disaster to the Wilkes Exploring Expedition. The main gold-bearing area was, therefore, practically an unknown land. The appearance in 1850 of Philip T. Tyson's Geology and Industrial Resources of California was consequently important. Tyson seems to have gone to California in 1849 as a private citizen, but so great was the demand for information concerning the region that on his return he made a report to Col. J. J. Abert, which was printed as a Senate document the year following.

Tyson's Work in California, 1849-1851.

In this report Tyson gave eight sections across the gold country, two of which extended from the coast to the Sierras.. These were published as mere outlines, showing the direction of the dip of the rocks, but with no pretense to scale. He described the western flank of the Sierras as consisting of a vast mass of metamorphic and hypogene rocks, stretching from the Sacramento Valley to the axis of the mountains. The metamorphic rocks, mainly slates, contained the veins of auriferous quartz, through the breaking down of which had been derived the gold found in the gravels of the ravines.

Making all due allowance for Tyson's laudable desire to check the wide and rapidly spreading excitement, bordering almost upon insanity, caused by grossly exaggerated accounts of the richness of the mines, still it would seem as if through overzealousness, or perhaps through actual ignorance, he underestimated their value, both to his own and others detriment. But it must be remembered that at that time and in that remote region, deposits, either placer or in veins, that could to-day be profitably worked, were valueless. He warned prospective investors that the large bodies of gold-bearing quartz found on the surface would if followed be found to be "nothing more than descending veins securely held between solid rocks, and that the cost of mining such was enormous, whilst the chances were almost wholly against their containing gold in proportion that would pay expenses." Indeed, Tyson regarded the prospect of a profitable mining of the veins as "altogether too remote and uncertain to be relied on."

During the session of 1847–48 the legislature of Maryland passed an act providing for the appointment and commission of a "person of ability, integrity, and suitable practical and scientific attainments," who should act as agricultural chemist for the State. These requirements seem to have been met in the person of Dr. James Higgins, who received the appointment and held the office until 1858, during which time he issued five reports. The office was not really a geological one, and the matter is mentioned here as bearing upon the subject only indirectly. During the session of 1858 bills were brought before the legislature to have the title of the office changed to *geologist* and, again, to *chemist and geologist*. Both, however, failed. Higgins was succeeded in 1859 by the Philip Tyson above noted, whose first report of 145 octavo pages and appendix of 20 pages was issued February 14, 1860. Like the reports of his predecessor, this was given up very largely to a discussion of agricultural questions, but contained chapters on the Minerals Comprising the Rocks of the State; The Mineral Character of Rocks; The Consideration of the Rocks as Grouped into Geological Formations, and also their Geographic Distribution in Maryland; and on Chemical and Physical Geology, in which the question of the origin of soils through rock weathering was discussed.

Higgins's Work in Maryland, 1848–1858.

Tyson's Work in Maryland.

FIG. 51.—Philip Thomas Tyson.

The main interest in the work, from our present standpoint, lies in the colored geological map (and sections) which accompanied it, and which had the merit of being the first special map of the State, the area having, of course, been included in the general maps of Maclure and others. The various formations were classified according to the scheme of Rogers for the map of Pennsylvania, and a table given showing which of these were found within the State limits. The second report, which appeared in 1862, comprised 92 pages, and was given over almost wholly to a discussion of economic questions, including the soils and ores, coal, marbles, clays, etc. From the presence of fossil cycads, found associated with the iron ores, Tyson was disposed to consider these and the clays in which they occur as belonging to the oolitic period.[a]

[a] L. F. Ward, in his paper in the Nineteenth Annual Report of the U. S. Geological Survey, 1897–98, puts these down as Cretaceous (Potomac).

CHAPTER V.

THE ERA OF STATE SURVEYS, THIRD DECADE, 1850–1859.

The period of financial depression, which proved so fatal to the State surveys during the last decade, had run its course. Several new States had in the meantime been added to the Union, some of which showed commendable promptness in authorizing geological surveys. New organizations were thus formed in fourteen States, eight of which had made no previous attempt. These eight, in alphabetical order, are California, Illinois, Iowa, Kentucky, Mississippi, Missouri, Texas, and Wisconsin. Six States for the second time undertook the work—Michigan, New Jersey, North and South Carolina, Tennessee, and Vermont. The National Government was also active, the most important undertaking being the surveys in connection with the proposed Pacific railways. In addition to these, Capt. R. B. Marcy made a survey of the Red River region of Louisiana, Maj. W. H. Emory one of the Mexican boundary, and Colonel Pope one into the arid region of New Mexico along the thirty-second parallel. To each and all of these expeditions geologists, or at least naturalists, were attached. In the British provinces Logan's survey was doing good service, while Dawson, alone and unofficially, was working in Nova Scotia.

This was an era of publication, not merely of reports, but of books. Emmons's American Geology, Dawson's Acadian Geology, Hitchcock's Geology of the Globe, Lesley's Manual of Coal and his Iron Manufacturer's Guide, Owen's Key to the Geology of the Globe, and Whitney's Metallic Wealth of the United States were among the more important local productions. The publication of by far the greatest importance of this decade was, however, the long-delayed report of the Pennsylvania survey, to which allusion has been made elsewhere two ponderous quartos which were truly epoch-making, although many of the more striking features had found their way into print elsewhere. The issuance of Murchison's Siluria, the ninth edition of Lyell's Principles, and F. Roemer's Die Kreidebildungen von Texas were also matters worthy of note. Hitchcock's Surface Features belongs to this era, and marked the beginning of systematic study along lines of physiography. Among the new names will be found those of W. P. Blake, J. W. Dawson, Leo Lesquereux, Oscar Lieber, William Logan, James G. Percival, J. S. Newberry, James Safford, G. C. Swallow, Alexander Winchell, and Amos H. Worthen.

An agricultural and geological survey of Mississippi was inaugurated in connection with the State University through an act of the legislature approved March 5, 1850. Under this act Dr. John Millington was appointed professor of geology and agriculture, in connection with the professorship of chemistry, which he already held. Professor Millington, however, relinquished the situation the latter part of 1850 without having made a report, and in 1852 was succeeded by Prof. B. L. C. Wailes. Professor Wailes made but one report, this an octavo volume of 356 pages and an appendix. Of this, but pages 207 to 288 deal with matters strictly geological. The work is by no means of a high order and made no permanent impression upon the science of geology either in the State or country at large. His colored sections are crude and the language pedantic. In fact, there is scarcely a single original observation which can be unhesitatingly accepted, owing to the general air of unfamiliarity with the subject that everywhere prevails.

Millington and Wailes's Work in Mississippi, 1850–1852.

He made no attempt to classify the rocks he described otherwise than Cretaceous, Tertiary, and Quaternary, and inferentially classed among the latter the sandstones of the Grand Gulf group, which he mentioned as overlying the Diluvial gravel. He traced correctly, according to Hilgard, the northern limits of Grand Gulf formation from the Mississippi across the Pearl River to Brandon, and described its occurrence in southwestern Mississippi.

In 1851 Ebenezer Emmons, heretofore connected with the survey of New York, was appointed State geologist of North Carolina, a position he continued to hold until the time of his death in 1863, though the work of the survey came to a close in 1860, owing to the outbreak of the civil war. Emmons was assisted by his son, Ebenezer Emmons, jr., and during his period of office issued five reports, the first, bearing the date of 1852, forming an octavo pamphlet of 181 pages. It related principally to the geology of the eastern counties and the coal. Emmons recognized the fact that the coal-bearing rocks of North Carolina were not of the same age as those of Pennsylvania, and regarded them as presumably of the same age as those of the Richmond coal fields, which at that time were thought by Prof. W. B. Rogers to be Liassic, though Emmons questioned if they might not be Permian or Triassic.

E. Emmons's Work in North Carolina, 1851.

The finding of saurian remains in the sandstones he regarded as pointing to their possible Permian age, though—

The meager list of plants and animals * * * furnish only grounds for conjecture to what age the formations belong. My opinion, derived from all the facts and circumstances known to me, inclines me to adopt the belief that it is the upper New

Red sandstone. Still, if the Richmond coal basin is of the same age as the coal rocks of North Carolina, geologists will be disposed to place the series along with the Oolites or Lias, as Profs. W. B. Rogers and Sir Chas. Lyell have done.[a]

Emmons in this work rejected completely the old Wernerian classification of (1) Primitive, (2) Transition, and (3) Tertiary, and introduced that given in tabular form below. It seems to have met with little favor, and was not, so far as the present writer is aware, adopted in a single instance elsewhere.

EMMONS'S ROCK CLASSIFICATION, PROPOSED IN 1852.

I. Pyrocrystalline—crystallized by the agency of fire. Primary of authors.
II. Pyroplastic—molded by fire. Ancient and modern volcanic rock of authors.
III. Hydroplastic—molded by water. Sediments of authors.

The first class is divided into two sections:

1. Unstratified pyrocrystalline, as granite, hypersthene rock, pyrocrystalline limestone, sienite, magnetic iron ores.

2. Stratified pyrocrystalline gneiss, mica slate, talcose slate, and hornblende steatite.

The second class is divided into two sections, also:

1. Modern pyroplastic rocks, lavas, tuffs, pumice, and all the products of volcanoes, which are cooled in the air.

2. Ancient pyroplastic rocks, the ancient lavas, cooled under water, basalt, porphyry, and green stone.

The third class is divided into systems, most of which are admitted by geologists of this day.

The systems belonging to the class of hydroplastic rocks, the consolidated and loose sediments, are exhibited in the following table:

I. Tertiary system:
  1. Postpliocene.
  2. Pliocene.
  3 Miocene.
  4. Eocene.
II. Cretaceous system:
  1. Upper Cretaceous, including the true chalk, with flints.
  2. Lower Cretaceous, including the green sand, iron sands, etc.
III. Wealdon, unknown in the United States.
IV. Oolite and Lias.
V. New Red Sandstone or Trias:
  1. Upper.
  2. Middle.
  3. Lower.

[a]At a meeting of the Boston Society of Natural History on January 4, 1854, Prof. W. B. Rogers summed up the evidence regarding the red sandstone of Virginia and North Carolina, and found it "to confirm the conclusion of their Jurassic date." The fossils thus far formed in the more western red sandstone belt and its extension through Pennsylvania and New Jersey showed this also to be Jurassic, a little lower probably than that of Virginia and North Carolina. He felt that there was little doubt but that the same conclusions would apply also to the sandstone of the Connecticut Valley.

VI. Permian system.
VII. Carboniferous system.
VIII. Devonian system.
IX. Silurian system.
  1. Upper.
  2. Lower.
X. Taconic system.

Emmons's second report, comprising 351 pages, was issued in 1856. It related chiefly to the geology and mines of the so-called midland counties. In 1858 his Report on the Agriculture of the Eastern Counties was issued. About one-third of this, notwithstanding its title, was given up to paleontological matters. In 1860 two more reports, both short, appeared—the one devoted mainly to agriculture and the other a special report on the swamp lands.

In the report for 1858 Emmons announced a principle which has since been enunciated in somewhat different words by our most eminent authority on soils. This, in his own words, is as follows:

> In the examination of soils the physical properties require as much attention as the chemical, for in order that a good chemical mixture of elements may be fertile they should possess a certain degree of adhesiveness or closeness which will retain water.

A good deal of attention was given to the marls of the State with reference to their availability for fertilizing purposes, though he recognized the fact that, unfortunately for the best interests of agriculture, these marls are too sandy to bear transportation to distant points.

A geological survey of Illinois was organized under an act of the general assembly approved February 17, 1851. This act authorized the governor, auditor, and treasurer to employ a competent geologist, who was required to make "a complete geological and mineralogical survey of the entire territory of the State," and provided that—

Norwood's work in Illinois, 1851–1857.

> The said geologist should proceed to ascertain the order, successive arrangement, relative position, dip, and comparative magnitude of the several strata or geological formations in the State, and to search for and examine all the beds and deposits of ores, coals, clays, marls, rocks, and such other mineral substances as may present themselves; to obtain chemical analyses of the same, and to determine by barometrical observations the relative elevation of the different portions of the State.

He was also required "to procure and preserve an entire suite of the different specimens found in the State, to be preserved and properly arranged in a cabinet, and placed in the office of the secretary of state in the State Capitol:" and eventually "to publish with the final reports a geological map of the State."

Under the provisions of this act Dr. J. G. Norwood was appointed State geologist, and the work was begun in October, 1851, by an examination of the formations exposed in the bluffs of the Ohio River between Shawneetown and Cairo.

The act appropriated the sum of $3,000 a year for carrying on the work. In 1853 the amount was increased to $5,000, with $500 additional for topographical purposes. Up to January, 1857, some $27,000 had been expended, though no report appears to have been made.

The usual trials of a State geologist seem to have come upon the path of Mr. Norwood and perhaps some that were unusual. Be that as it may, a committee was appointed to investigate the conditions of the office. The committee reported, however, that in their belief the money had been well expended, a large amount of work had been done, and that well done, and they recommended an appropriation of the sum of $6,500 to enable Mr. Norwood to complete a report on the economic resources of the State, on which he was then engaged.

Fig. 52.—Joseph Granville Norwood.

The report of the committee seems, however, to have failed of its purpose, since the only outcome was a small octavo pamphlet of less than 100 pages devoted wholly to a discussion of the coals of the State, accompanied by a considerable number of analyses. This report bore the date of 1857, and was Norwood's last as well as first.[a] It was accompanied by a small, one-page, colored geological map of the State.

Presumably, all members of the legislature were not as favorably disposed toward Doctor Norwood as were the members of the investigating committee, for the following year (1858) he was supplanted by Mr. A. H. Worthen, who had been connected with James Hall on the State survey of Iowa.

Second Attempt at a Geological Survey of Indiana, 1852.

In 1852 the question of the reestablishment of the geological survey of Indiana was agitated, but nothing came of it until the following year, when, acting under a recommendation of Governor J. A. Wright, the legislature made a small appropriation to become available in January, 1854. With this for a beginning, the governor appointed Dr. Ryland T. Brown State geologist. The venture was, however, short lived. Brown made but one report, which the legislature refused to publish, and at the same time refused further appropriation for continuing the survey,

[a] In 1855 Norwood, in connection with Mr. Henry Patton, published in the Journal of the Academy of Natural Sciences a paper comprising some 77 pages of text relating to the work thus far done.

the main reason given for such action being an overvaluation of the Indiana coals on the part of Brown. The report, it should be mentioned, was subsequently published in the report of the board of agriculture.

In 1852, in compliance with a resolution of the United States Senate, Capt. R. B. Marcy was directed to proceed "without unnecessary delay" to make an examination of the upper Red River and the country immediately bordering upon it from the mouth of Cache Creek to its sources. The officers of the expedition, which left Fort Belknap, Texas, on the 2d of May, consisted of Captain Marcy, in charge; Bvt. Capt. George B. McClellan, U. S. Engineer; and Dr. G. G. Shumard, the last named, in addition to his duties as surgeon, acting as naturalist. The report submitted formed an octavo volume of 320 pages with 65 plates, of which 25 may be considered as geological, 6 of these being of invertebrate fossils. The geological part proper comprised but 32 pages, which were by President Edward Hitchcock, of Amherst College. The invertebrate fossils were described by B. F. Shumard.

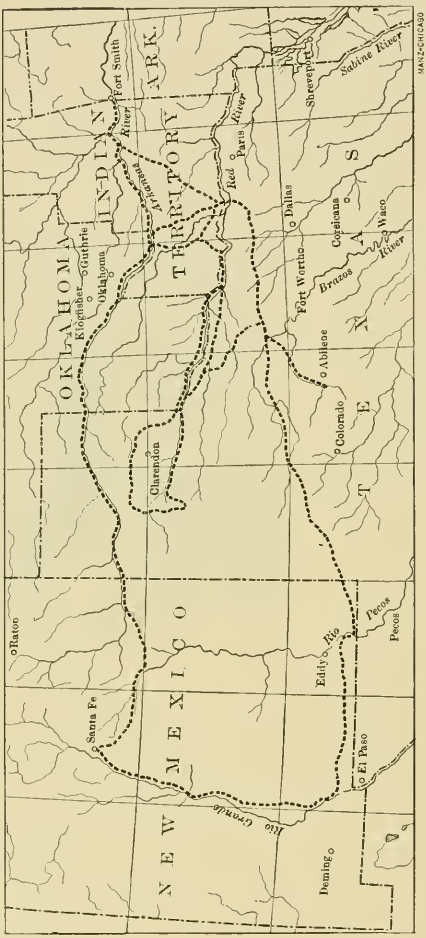


FIG. 53.—Map showing routes of Marcy and Shumard, 1849–52.

G. G. Shumard's Work in 1852.

Dr. G. G. Shumard's report consisted of a brief summary of the geology of a portion of northwestern Arkansas, which he considered as essential to a proper understanding of that which was to follow, succeeded by memoranda of the various types of rocks, minerals, and formations passed over each day. It was accompanied by a colored geological section from Fort Belknap, Texas, to Washington County, Arkansas, showing a granitic axis flanked on either side by Carboniferous limestone, in its turn overlaid by Coal Measures, and with Cretaceous deposits between Fort Wichita and Cross Timbers in Texas.

In the paleontological report by Dr. B. F. Shumard there were described Carboniferous fossils from Washington and Crawford counties, Arkansas, and Cretaceous forms from Fort Wichita and the Cross Timbers regions of Texas.

Hitchcock, in his report, dwelt particularly on the possible Carboniferous age of various beds of coal, reported by Shumard, and the economic value of the gypsum, as well as the ores of copper and gold. His reference to the canyons of the Red River is particularly interesting in view of his early writings regarding the Connecticut (p. 310):

> You seem in doubt whether this gorge was worn away by the river or is the result of some paroxysmal convulsion. You will allow me to say that I have scarcely any doubt that the stream itself has done the work. The fact that when a tributary stream enters the main river it passes through a tributary canyon seems to me to show conclusively that these gorges were produced by erosion and not by fracture.

Hubbard and Dana on Subaerial Erosion, 1852.

Two papers on the subjects of rock decay and erosion, of this year, are worthy of consideration. Prof. Oliver P. Hubbard, of Dartmouth College, during a study of the trap dikes, noted that the same could be traced continuously across the country, at varying levels, from mountain top to valley bottom. From this fact he argued that the valleys had been carved out through decomposition and erosion since the dikes were formed. The difference in altitude at the various outcrops gave, then, a measure of the amount of erosion.

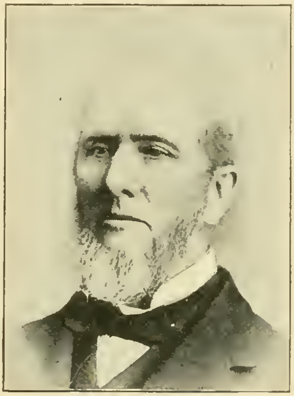


FIG. 54.—Oliver Payson Hubbard.

Dana's observations, though of a somewhat different nature, were none the less interesting. In writing on denudation in the Pacific, he took the ground that the ocean is powerless to excavate valleys along the coast, and that the deep valleys like those of Tahiti are due to subaerial decomposition and erosion, an observation no geologist of to-day would venture to doubt.

Trask's Geological Survey of California, 1853.

In March, 1853, by resolution of the senate of the State of California, Dr. John B. Trask was called upon to furnish information in relation to the geology of the State. As a result Doctor Trask submitted material issued in a pamphlet of 30 pages, published by the assembly in the session of 1853. By a joint resolution which passed the senate and assembly on May 6, 1853, Trask was authorized to make a further examination of some parts of the Sierra Nevada and Coast Range mountains. As a result of this and subsequent acts there were issued reports on the geology of the region mentioned in 1854, 1855, and 1856.

The classification adopted by Trask was that of the older geologists of his time, the rocks being divided merely into Primary, Secondary, and Tertiary. Although fossils were found, he did not attempt to describe them, and seemed in most cases to fail to realize their value as indicative of any particular geological horizon. His ideas regarding metamorphism were somewhat crude. Thus, he stated in his first report:

It is a well-known fact that intrusive dikes of trap in passing through limestone will change the calcareous formation to true talcose rocks.

He divided the State into three divisions: First, a primary or central district, included between latitude 38° 30′ and 40° north; second, the northern district, included between 40° and 42° north; and third, the southern district, included between 38° 30′ and 36° north. The rocks of the primary district, he stated, are for the most part primitive, being composed of granite, porphyry, trap, and other allied rocks, of which serpentines form the one important part. The sedimentary rocks of the district were divided into first, argelite (*sic*) slates; second, conglomerates; and third, sandstones, the last named being regarded as probably of Miocene age.

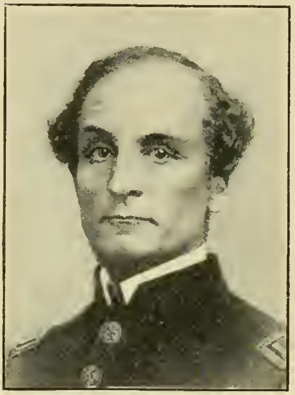


Fig. 55.—John Boardman Trask.

The rocks in the northern district were described as of essentially the same character, a few minor differences only being noted. The southern district contained many rocks in common with the other two, although there were in addition many basaltic areas. He found a primary limestone in the area between the American and Merced rivers, and evidence of at least three successive periods of upheaval in this portion of the continent.

In his second report he described the geology of the most elevated portions of the counties of Butte, Sierra, Yuba, Nevada, and Placer; also the more southern counties of San Francisco, Santa Clara, Santa Cruz, Monterey; the north part of San Luis Obispo, Tulare, Mariposa, Tuolumne, Alameda, Contra Costa, and San Joaquin. During the months of October and November he visited Nevada and Calaveras counties. He pointed out the presence of post-Pliocene fossils in argillaceous sandstone of the Coast mountains between Point Pinos and Nacismiento River. He divided the Tertiary rocks as below:

Period.	Group.	Where found.
Eocene	Middle	Calaveras County, at Murphys and other localities. Bones of extinct animals, etc.
Miocene		North and south of San Francisco in the Coast and Monte Diablo mountains. Consisting of marine shells, with most of the species extinct.
Pliocene	Lower	Coast mountains and Gabilan Spur. Also in cavern deposits in Calaveras County.
Post-Pliocene		Southwest of Monterey. Marine shells, all of existing species.

He had no hesitation in saying that no coal would be found in any part of the Coast Range south of the thirty-fifth parallel of north latitude, though the presence of a supposed Carboniferous limestone in Shasta County led him to express a hope that the desired material might yet be found within the limits of the State.[a] In his report for 1855 the predominating fossiliferous rocks of San Luis Obispo and Santa Barbara counties were considered to be of Miocene age. The San Bernardino Mountains were described as made up for the most part of primitive rocks, granite forming by far the larger part of their highest ridges and peaks.

In this connection it is well to note that, at the request of A. D. Bache, of the Coast Survey, W. P. Blake prepared in 1855 a brief paper on the physical geology and geography of the coast of California from Bodega Bay to San Diego. Blake regarded the sedimentary rocks of Punta de los Reyes as probably of Miocene age, the sandstone at the entrance of San Francisco Bay as Tertiary, and the metamorphic rock of the peninsula as an altered sandstone. The serpentine of Lime Point was shown to be eruptive, as was also the granite of Cypress Point and the Bay of San Carlos, and younger than the conglomerate.

Swallow's Geological Survey of Missouri, 1853.

This same year (1853) there was organized a geological survey of Missouri with G. C. Swallow at its head, and Dr. A. Litton, F. B. Meek, Maj. F. Hawn, and Dr. B. F. Shumard as assistants. Five reports were published. The first, bearing the date November 10, 1853, consisted of but four pages. The second, dated 1854, comprised over 400 pages, including the reports of the assistants above mentioned. None of the sections nor maps given were colored, nor were any new principles or striking

[a] These hopes were partially realized, lignite coal, but of Cretaceous age, having been found and to some extent worked in Alameda, Amador, Contra Costa, Fresno, Kern, Monterey, Orange, Riverside, and San Bernardino counties.

features brought out. The work as a whole is an extremely uninteresting array of details, essential to the geographical extension of geological knowledge. Some space was devoted to economic geology, a consideration of soils, etc. Doctor Litton's report consisted almost wholly of details of lead, copper, and iron mines. Perhaps the most important economic item in Meek's report was his calling attention to the limited area of the coal beds, which lie in narrow basins in the encrinal limestone.

The third annual report of progress (6 pages) appeared in 1857, the fourth (14 pages) in 1859, and the fifth (19 pages) in 1861. G. C. Broadhead, who later was himself State geologist, became an assistant during 1857–1861, J. G. Norwood in 1858–1861, Henry Engelmann in 1857, and Dr. John Locke in 1860.

During the period which intervened between the publication of the second report and the stopping of the survey in 1861, a large portion of the State had been visited by members of the corps, and full reports were written on the following counties: Cape Girardeau, Perry, St. Genevieve, Jefferson, Crawford, Phelps, Pulaski, Laclede, Wright, Ozark (including Douglas), Clark, Morgan, Miller, Saline, Chariton, Macon, Randolph, Shelby, Osage, and Maries.

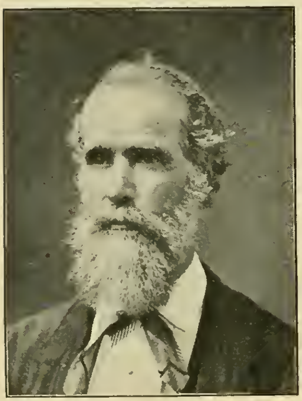


Fig. 56.—Garland Carr Broadhead.

After the survey had been discontinued the legislature authorized L. D. Morse and G. C. Swallow to publish all the results of the work of the previous seven years, but the project was abandoned on account of the expense.

While nearly all the State and land-office surveys organized up to 1850 had economic ends in view, and while, further, numerous papers of a more or less economic character had appeared from the hands of various writers from time to time, yet literature relating to American ore deposits remained scant and of an extremely unsatisfactory character.

J. D. Whitney's Metallic Wealth of the United States, 1854.

The appearance in 1854 of Whitney's Metallic Wealth of the United States marked, therefore, an important epoch. The work comprised upward of 500 octavo pages, and though written with especial reference to the ore deposits of the United States, contained references to those of all the principal foreign localities as well and remained the standard work of reference up to the time of the appearance of Kemp's Ore Deposits of the United States in 1893.

Many of the principles set down by Whitney have, naturally, been shown to be erroneous, as he himself lived to recognize. Thus, regarding the occurrence of gold, he wrote:

In general it may be said that the older the geological formation the greater the probability of its containing valuable ores and metals.

And further:

There is room for doubt whether the great gold deposits of the world did not originate exclusively in the Paleozoic strata, since we are not aware that the rocks which have been proved to be of Azoic age have been found to be auriferous.

In this, it will be noted, he followed the teaching of Murchison.

To the reader of to-day it will seem scarcely possible that, at the date of Whitney's writing, there were no mines worked for silver alone in the United States, the supply of the metal coming almost wholly from the native gold of California. Argentiferous galena had been worked to a slight extent, as at the Washington mine in Davidson County, North Carolina, but work was suspended at the time of his writing. How little the silver resources of the West were realized is shown by Whitney's comment on the rapid increase of the gold output from year to year and the comparative decrease in that of silver. He wrote:

Silver is, in a geological point of view, the metal best adapted for a standard of value, since, possessing all the valuable qualities which make gold suitable for that purpose, it is not liable to those fluctuations in its production to which this latter is exposed. There is no discovery of a new continent to be looked forward to whose mines shall deluge the world with silver, and any increase in the amount of this metal produced must come chiefly from the working of mining regions already known.

Yet Whitney himself lived to see the annual output of American silver become so great as to practically remove it from the list of precious metals and cause it to be rejected for all but subsidiary coinage.

Whitney recognized the fact that none of the deposits of lead in the Mississippi Valley could be considered as coming under the head of true veins (i. e., fissure veins), and that the productive deposits did not generally exceed a hundred feet in thickness in the Galena (Lower Silurian) limestone immediately overlying the Trenton. No ore of consequence was known to occur in the so-called "Blue Limestone" (Trenton, Bird's-eye, Chazy, and Black River) and it was not considered probable that the fissures would ever be found to extend through the intervening sandstone into the Lower Magnesian beds. Sinking through the sand into these latter beds was, therefore, considered as mere random exploration and a foolish enterprise.

He classified the ore deposits as (1) simple alluvial deposits which were recognized as residual from the decomposing limestone; (2) deposits in vertical fissures which had a very limited longitudinal extent, and (3) deposits in flat sheets. All of these were regarded as deposits from aqueous solution which took place either in depressions of the surface or in vertical fissures of the nature of gash veins produced by the shrinkage of the calcareous strata.[a]

These views differed from the more modern in that it is now deemed as probable that the ores were first precipitated in an ocean in which they were held in solution as sulphates and reduced to sulphides through the decomposing organic matter; that subsequently, through the action of percolating surface waters, the same were once more oxidized, segregated in the fissures, and reduced a second time to the condition of sulphides. The production of the mines in the Mississippi Valley he regarded as having even then reached its maximum.

Whitney recognized the eruptive nature of the Iron Mountain masses of Missouri, and apparently regarded the hematite ores of the Lake Superior region as also of an eruptive nature (see also p. 417), though the later work of Van Hise has shown them to have had a chemical origin. Concerning the specular and magnetic iron ores of New York, he thought to have found the evidence of direct eruptive origin as perhaps less conspicuous, many exhibiting appearances of secondary action, such as might have been brought about by volcanic agencies and powerful currents which swept away and abraded portions of the original eruptive masses, "rearranging their particles and depositing them again in the depressions of the strata." The lenticular beds of ore occurring parallel with the stratification were particularly referred to as originating in this way.

A year later (November, 1855) Whitney had in the American Journal of Science an article on the changes which take place in the structure and composition of mineral veins, which is of interest in connection with the recent revival of the subject of secondary enrichment of ore deposits. He here described the now well-known copper deposits of Ducktown, Tennessee, and the superficial alteration of the vein matter, and called attention to the fact that the black ore, then being mined, was formed by a process of natural concentration by surface water, which was constantly decomposing the material above the permanent water level and carrying it downward to the point where it was stopped by the solid portion of the vein. By this means a large portion of the copper once disseminated throughout perhaps 100 feet of vein stone had become concentrated into a thickness of perhaps 2 or 3 feet.

In June, 1854, Lewis Harper, or properly, Ludwig Hafner, was elected by the trustees to the chair of geology in the University of

[a] Dr. Henry King, in a sketch of the geology of the Mississippi Valley, read before the Association of American Geologists and Naturalists in 1844, and printed in the American Journal of Science for that year, argued that the ores of zinc, copper, and lead occurring in the Cliff limestone were deposited contemporaneously with the inclosing rock.

Mississippi, which act, under the law, constituted him also as State geologist, and Millington, whose work is mentioned on p. 430, was forced to resign.

Harper's Work in Mississippi, 1854–1857.

In 1855 Harper was relieved of a portion of his duties as instructor in the university in order that he might personally take the field, and an appropriation of $1,000 secured for the employment of an assistant geologist, which place was offered to Eugene W. Hilgard, then fresh from studies at Heidelberg. Hilgard and Harper worked together during the season of 1855, but the dual position of State geologist and professor in the university proved unsatisfactory to the trustees; the law was repealed in 1856, and Harper also forced to resign, though Hilgard was continued as an assistant.

At the legislative session of 1856–57 Harper succeeded in securing the passage of an act providing for the printing of the second annual report of the agricultural and geological survey of the State and for other purposes. This resulted in a complete separation of the survey from all connection with the State university, the establishment of a geological survey, and the office of a State geologist at a salary of $2,000 a year, with an appropriation of $1,200 for fitting up a chemical laboratory. Three thousand five hundred dollars was appropriated for the publication of Harper's report. Concerning this report, Hilgard remarks:

> It need only be said that it is a literary, linguistic, and scientific curiosity, and probably unique in official publications of its kind. It was the labored effort of a sciolist to show erudition, and to compass the impossible feat of interpreting and discussing intelligently a considerable mass of observations, mostly recorded by another, working on a totally different plan from himself.

The report contained a colored geological map of the State which, though less detailed, corresponded in a general way with that published later (1860) by Hilgard. Indeed, there is every reason for supposing that the map itself was compiled largely from Hilgard's notes. The work, like its predecessor, had little influence upon geological thought, and was, if not ignored, unfavorably reviewed by the journals of the day. The circulation of this report throughout the State brought discredit upon its author to such an extent that, toward the end of the year (1857), he was obliged to resign his office.[a]

[a] This Geological Report on Mississippi is very unequal in its different parts and requires a careful revision before it can become good authority. Many of the sections have a fantastic boxing off of layers which is quite unintelligible to us. Certain rocks are pronounced to be Carboniferous, because the genus *productus* occurring in them is not known to exist, the author says, in older strata. Some peculiar concentric aggregations in clay are attributed to whirlpools in the waters. The work argues against the subdivisions of the Eocene proposed by Conrad on very insufficient data and an evident want of appreciation of the subject. There are errors, also, in the identification of the Cretaceous, Tertiary, and post-Tertiary beds which betray insufficient observations and an imperfect acquaintance with the science. (Am. Jour. Sci.)

Under an act of the Wisconsin legislature, approved March 25, 1853, Edward Daniels was appointed State geologist, but at the end of the year was superseded by Dr. J. G. Percival, whose work in Connecticut has been already referred to (p. 329). Daniels's first and only annual report, bearing date of 1854, consisted of a small octavo pamphlet of 82 pages, devoted largely to a consideration of the lead fields. One geological section in black and white was given, extending across the lead mines from the Mississippi River opposite Dubuque to the Blue Mounds. The rocks were classified, beginning with the uppermost, as (1) coralline beds, (2) gray limestone, (3) blue limestone, (4) buff limestone, (5) sandstone, (6) lower magnesian limestone, and (7) the sandstone of the Wisconsin River. A vertical section was also given showing the succession and relative thickness of the rocks underlying the lead regions. In this last the gray limestone was given as the prevailing "surface rock of the mines, containing veins of lead, and, in its lower beds, zinc and copper."

Daniels's Work in Wisconsin, 1854.

Daniels found evidence, as he thought, to strengthen the conjecture of Owen to the effect that the Lower Magnesian limestone would be found to contain lead ore in workable quantities.

Aside from the above-noted publication, Daniels was the author of an article on the Iron Ores of Wisconsin, in the report of the geological survey of Wisconsin for 1857 (62 pages), and a brief note regarding the lead district of Wisconsin, which appeared in the Proceedings of the Boston Society of Natural History in 1854.

According to Hall, Daniels in 1855 first pointed out the unconformity of the western coal measures with the older rocks, though J. W. Foster in 1856 published a section showing a similar unconformity, the discovery of which he credited to Norwood.

Doctor Percival, who succeeded Daniels, received his appointment in August, 1854, and served until the time of his death, which occurred on May 2, 1856. Two reports, in the form of octavo pamphlets of about 100 pages each, were issued as the result of his work. Like his previous work in Connecticut, these reports are extremely prosy and made up largely of very minute descriptions of the lithological nature of the various rock formations of the State, their geographic distribution and relative position. Fossils were mentioned only occasionally, and, otherwise than his reference to them as primary and secondary rocks, there is no suggestion as to their probable geological age, with the exception of the reference in the second report to the fact that the so-called "Mound limestone" had been regarded from its fossils as equivalent to the Niagara limestone. The character of the ore deposits, and the position, number, and character of the veins were noted with great detail,

Percival's Geological Survey of Wisconsin, 1854.

and in a single instance he indulged in a little speculation regarding the origin of the ore:

The appearances seem no less to indicate the origin of the mineral and the accompanying ores from beneath, probably from the primary rocks underlying the lowest secondary; and that they rose in such a condition that they were diffused through a certain definite extent of the materials of the rocks, and then segregated in their present form, and this along certain lines which have determined their arrangement.

April 8, 1854, D. D. Owen was appointed State geologist of Kentucky, a position which he continued to fill until the time of his death in 1860. During this time there were issued four large octavo reports, comprising, all told, upward of 2,000 pages, with sections, maps, and plates of fossils. Owen was assisted at first by Dr. Robert Peter, chemist, and Sidney T. Lyon, topographer; later, Leo Lesquereux, paleobotanist. E. T. Cox, geologist, and Joseph Lesley, topographer, were added to the force.

Owen's Geological Survey of Kentucky, 1854–1860.

Owen divided the formations of the State as follows, beginning with the uppermost: (1) Superficial deposits, (2) the Coal Measures, (3) sub-Carboniferous limestone, (4) Black lingula shales, (5) Gray coraline falls limestone, (6) the Chain coral and Upper Cliff limestone, and (7) the Blue, Shell, and Bird's-eye limestone, the last named being the most ancient of any yet found within the State limits.

As with a majority of Owen's works, these reports are given up largely to economic matters, to descriptions of the coal, iron ores, building stones, and other useful minerals.

A local epidemic of milk sickness in cattle was examined into in considerable detail by Owen, who concluded that the disease was "intimately connected with the geological formation," and probably due to the presence of soluble salts of aluminum, iron, and magnesia, produced in the shales by the decomposition of iron pyrites. He showed an amusing tendency to magnify the importance of minor matters in suggesting that the animals at pasture may have become weakened and peculiarly susceptible to disease through breathing, while feeding with the nostrils close to the ground, an atmosphere deficient in oxygen, the abstraction of this element being due to the oxidation of the pyrite in the surface rock.

Concerning the roe or oolitic structure of the sub-Carboniferous limestone, he wrote, the structure "seems to have been formed in eddies where the water circled round in spiral or funnel-shaped currents which kept particles of fine sand revolving in such a manner that they acquired concentric calcareous coatings, until, having attained the size of fish roe, their gravity was sufficient to overcome the power of suspension of the rotary currents, when they sunk to the bottom." In consideration of the fact that this oolitic structure is now known to prevail over many hundred square miles of area, this explanation seems scarcely sufficient.

Peter's work on the chemical composition of the soil was very thorough, and, taken all in all, the work done by this survey on problems relating to the soil was of greater importance than any previously produced. The method followed by Doctor Peter himself has, however, been proven by recent work to be of comparatively little value, the fertility of a soil, as announced years earlier by Emmons, being dependent more upon its physical than chemical properties.

G. G. Shumard's Work in Connection with Pope's Expedition, 1855.

In 1855 G. G. Shumard accompanied, in the capacity of geologist, the expedition under command of Captain Pope for the purpose of boring artesian wells upon the western plains along the line of the thirty-second parallel. An abstract of his report was given in the Transactions of the St. Louis Academy of Sciences, I, 1856–1860, though, so far as can be ascertained, no final report ever appeared.

Shumard announced the finding of Permian fossils about 30 miles above the mouth of Delaware Creek, in the country lying between the Rio Pecos and the Rio Grande. At Delaware Creek the oldest rocks were Cretaceous, overlaid by Quaternary. The Guadalupe Mountains he described as consisting of white, gray, and bluish-black limestone, containing fossils, some of which appeared to belong to the Coal Measures and others to the Permian, the beds being finally set down as of Permian age. The Sierra Alto was shown to have a granitic nucleus, from which the stratified rocks dip away on either side.

Fig. 57.—Oscar Montgomery Lieber.

Silurian rocks were found in the El Paso Mountains, and the Jornada del Muerto was shown to be a small trough composed mostly of limestone, sandstone, and shales, covered to a depth of 5 or 6 feet with loose detritus. The upheaved edges of these underlying strata formed the mountains on either side. The Organ Mountains were shown to be of limestone, belonging to the Coal Measures.

Lieber's Work in South Carolina, 1855–1860.

By an act of the legislature of the State of South Carolina in 1855 Oscar M. Lieber was appointed director of the geological, mineralogical, and agricultural survey of the State, a position which he held up to 1860. During this period he made four annual reports, the first bearing date of 1857 and the last 1860. This, it will be remembered, was the third survey of the State undertaken at public expense, the first being purely agricultural, under the direction of Edmund Ruffin, and the second geological and agricultural, under direction of M. Tuomey.

In the reports of Lieber matters of both theoretic and economic nature received attention, though an undue amount of space was perhaps devoted to a discussion of the itacolumite, which he considered to be a true sandstone. He differed in this respect with Mr. Tuomey. Its flexibility he regarded as not due to decomposition, but rather to its fineness of grain and admixture of mica or talc, delicately laminated structure, and a certain degree of compactness in the constituents of each lamina. In this he was mistaken. He discussed the origin of the rock, and compared it with the itacolumite of Brazil in its relation to the diamond.

A peculiar tendency on the part of Lieber to use outlandish terms, particularly Brazilian Portuguese, is manifested in this report. Thus, in his paper on the itacolumite and its associated rocks, he mentions finding the "*tapanhoancanga*, or *canga*, which sometimes passed into a reddish quader-sandstone." He also wrote of the "*oryctognostic*" composition of the rock, and designated a prospector as a "*costeaner*."

He classified the igneous rocks of the State, commencing with the newest, as:

Trachytic rocks:
- Eurite and quartz porphyry (?).
- Coarse trachyte of eastern Lancaster.
- Domite, phonolith.

Trappean rocks: Diorite and Diorite slate, soapstone (?), Talcose trap (?).

Granites:
- Melaphyre, Egeran (?).
- Aphanitic porphyry.
- Coarse-grained granite, etc., of Taxahaw (syenite).
- Other granite and gneiss.

(The marks of interrogation with some of these denote that their exact relative position is not established.)

Lieber's views regarding mineral veins and ore deposits were largely influenced by those of European authorities, but, nevertheless, he entertained certain independent ideas which at this date are instructive. He believed with Werner that the veins were filled crevices, but thought them to have been filled from below rather than from above; that is, the minerals constituting the veins he regarded as having been derived from the interior of the planet and brought to the surface by mineral waters or steam, where they were deposited chiefly in the crevices themselves, the surplus only distributing itself among the surface waters, whence it was afterward precipitated.

He argued against the idea that the veins had been filled by the leaching action of water permeating the rocks on either side, saying:

> Entirely the reverse is, however, the case. Thus, minerals which belong to the veins but which are found in the country were in reality derived from the former; the vein crevices were the first reservoirs, and the few scattering particles of the minerals of the veins which we find in the adjacent country rocks found their way into the latter by elimination or secretion and by sublimation from the surcharged vein crevices.

Concerning the variation in vein structure and the changes of the contents of veins at various depths, he wrote:

Except in those few cases where the enrichment of a vein is due to extraneous or superficial causes, we may safely say that veins gain in the quantity of their metalliferous contents as we leave the surface; that is to say, the lodes increase in diameter and in the compactness of their ores.

Thus do we find one who was the best authority in the State promulgating a theory wholly erroneous and misleading.

The question of the origin of gold received consideration, and the opinion was expressed that "the gold in some igneous rocks with us and elsewhere may have been brought up with the fluid masses from beneath, but it may also have been imparted by the solution of auriferous sedimentary rocks traversed at the period of injection." While noting that dikes exerted a conspicuous influence on the discernible presence of gold, he believed that these did not impart the metal, or if they did, only in exceptional cases, and that as a rule certain sedimentary rocks must be regarded as the true source of the gold into which it was infused at the time of their deposition, though by what means or from what source he found it impossible even to guess.

Each of the reports was accompanied by two or more colored geognostic maps, in which the various formations were grouped according to their lithological nature rather than according to their geological age.

Dawson's Acadian Geology, 1855.

In 1855 there appeared Dawson's Acadian Geology, a small octavo volume of but 388 pages, but which, through successive editions, grew, by 1878, to nearly 800 pages. This in all its editions was by far the most important production of this most prolific writer.[a] The edition of 1855 contained a colored geological map of the region and purported to give in a condensed form what was known of the more general features of the peninsula. A discussion of the views held, and as subsequently modified, can well be reserved until we come to the edition of 1878.

Dawson's work in Nova Scotia, 1853-1865.

A very large proportion of Dawson's geological papers related to the Coal Measures of Nova Scotia and their included plant and animal remains. His first publications on these subjects date back to 1843. As early as 1853 he announced, in connection with Lyell, the finding, at the base of an upright fossil tree trunk in these Coal Measures, of bones identified by Jeffries Wyman and Richard Owen as those of a reptile or batrachian, to which the name *Dendrerpeton acadianum* was applied. The finding of the shell of a terrestrial mollusk was also announced at the same time.

Dawson also made important observations regarding the origin of the various coal beds. He felt that the conditions indicated the existence at one time of a long succession of oscillations between terrestrial and

[a] Dawson's bibliography contains upward of 360 titles, of which at least nine were books.

aquatic circumstances, which were not accompanied by any material permanent change in the nature of the surface of the land and its organized inhabitants. He conceived that the elevation and depression of large areas were not absolutely contemporaneous, but such that by a mere change of place one could have passed from a coal swamp to a modiola lagoon or a tidal sand flat.

In the Quarterly Journal of the Geological Society for 1859 Dawson had another important paper on the vegetable structures in the coal in which he announced that the vegetable matter of these beds consists principally of Sigillariæ and Calamiteæ. With these, however, he found intermixed remains of many other plants.

The structure of the coal as he here found it conformed to the view that the materials were accumulated by growth in place without any driftage of materials. The rate of accumulation he thought to have been very slow, the climate of the period being such that the true conifers grew not more rapidly than their modern congeners. Making all due allowances, he felt safe in asserting that every foot of thickness of pure bituminous coal implied the growth and fall of at least fifty generations of Sigillariæ and, therefore, an undisturbed condition of forest growth enduring through many centuries.

In this same journal for 1865, under the title of On the Conditions of the Deposition of Coal, he again referred to the subject. Writing with reference only to the beds of Nova Scotia and New Brunswick and their associated sediments, he showed that the coarser matter of the Carboniferous rocks was derived from the neighboring metamorphic ridges, but much of the finer material was probably drifted from more distant sources. He thought there was no good reason to doubt that in the Carboniferous period the greater part of the Laurentian and Silurian districts of North America existed as land. Considering the relative position and lithological nature of the beds of the Carboniferous period, and comparing them with those of other periods of the Paleozoic age in eastern America, he thought to find indications of the existence of periodic cycles such that similar beds were deposited at corresponding periods in each, the parallelism being tabulated as below: (The several formations are arranged in descending order.)

Character of group.	Lower Silurian.	Upper Silurian.	Devonian.	Carboniferous.
Shallow, subsiding marine area, filling up with sediment.	Hudson River group.	Lower Helderberg group.	Chemung group..	Upper coal formation.
Elevation, followed by slow subsidence, land, surfaces, etc.	Utica shale	Salina group ...	Hamilton group..	Coal Measures.
Marine conditions; formation of limestones, etc.	Trenton, Black River, and Chazy limestones.	Niagara and Clinton limestones.	Corniferous limestone.	Lower Carboniferous limestone.
Subsidence; disturbances; deposition of coarse sediment.	Potsdam and Calciferous sandstones.	Oneida and Medina sandstones.	Oriskany sandstone.	Lower Coal Measures and conglomerate.

In an article communicated to the Natural History Society of Montreal in 1860, Dawson claimed to recognize "among the partially metamorphosed sub-Carboniferous rocks of Nova Scotia, formations ranging from the Middle Silurian to the Lower Devonian, inclusive, but of a more argillaceous and less calcareous character than the series occupying this position in the mainland of America." The granites (intrusives) he regarded as of newer Devonian age, and the Arisaig series as representing "the upper part of the Middle Silurian, probably with a part of the Upper Silurian, a position much lower than that assigned to it in my Acadian Geology."

Jules Marcou's Geological Map of the United States, 1853.

In 1853 Jules Marcou, a Frenchman who had come to America in 1848, published a geological map of the United States and the British Provinces of North America, with 92 octavo pages of explanatory text, two geological sections, and eight plates of the fossils which characterize the formations. The map, which was colored by hand, extended as far west as the one hundred and sixth meridian, and the geological sections, not colored, extended, the first from the Atlantic Ocean at Yorktown, Virginia, to Fort Laramie, Nebraska, and the second from Lake St. Johns in the Hudson Bay Territory to Mobile, Alabama.

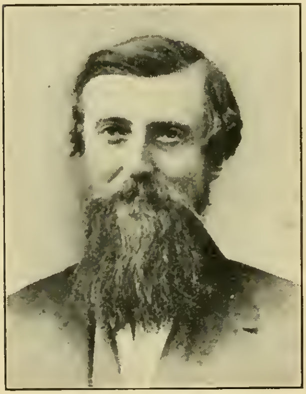


FIG. 58.—Jules Marcou.

The author adopted the formation names established by M. de Verneuil and Murchison, in order to render possible a satisfactory comparison with the existing geological maps of England, Germany, Russia, Scandinavia, and Bohemia. The divisions Cambrian and Taconic, however, were not recognized, since, in the opinion of the compiler, they "ought to disappear from geological classification, for they give two names to the metamorphic rocks, of which they are integrant parts, in all regions where these beds have been observed."[a]

Perhaps the most striking feature of the map, at least that in which it differs the most from those of later date, lay in the enormous development of the Devonian, which is made to occupy a large portion of southern New York, as now, and to extend thence in a continuous, broad, but gradually narrowing band southwesterly to near Tuscaloosa, in Alabama. A continuous belt was also indicated as extending from the east side of the south end of Lake Michigan westerly nearly to the Missouri River. The brown Triassic sandstones of the Eastern States were colored as Keuper (yellow), and the belt west of Rich-

[a] This statement regarding the Taconic is a little surprising when one considers the part Marcou played in the subsequent controversy (see p. 659).

mond and one near Raton Mountains, in New Mexico, as Lias or Jurassic (blue). A band of Keuper was also represented as extending from the eastern end of the south shore of Lake Superior quite across the Coteau des Prairies to the ninety-eighth meridian. A continuous band, colored as composed of granite porphyry, syenite, greenstone, gneiss, mica-schist, etc., was represented as extending from below the twenty-fourth parallel in Mexico northward to the great bend of the North Platte in Wyoming, where it was overlain by Silurian, Devonian, Coal Measures, and Keuper strata, the latter flanked on the north by a broad band of "copper trap." Here again the series extended westerly to the edge of the map and northeasterly to a point about midway between Mandan and the Little Missouri River in Dakota.

This attempt on the part of Marcou was certainly commendable, requiring courage as well as judgment. Unfortunately, Marcou does not seem to have used discretion in all cases in the selection of his authorities, and made altogether too sweeping generalizations, often in direct contradiction of facts made known by other workers.

In 1855, 1858, and again in 1872 Marcou published in Germany and France other editions of his map, in which he comprised the whole country from the Atlantic to the Pacific Ocean. Perhaps the most striking feature of these issues is the enormous area of country west of the Missouri at Iowa and extending almost to Great Salt Lake and the Colorado River in Arizona, colored as red sandstone (Trias), with broad intercallations of Jurassic. This feature is the same on issues of both 1855 and 1858, although in the map of 1853 he colored the same area (at least as far as this map extended) Cretaceous, Tertiary, and Quaternary. In the edition of 1855 the entire west coast of California south of Humboldt and as far down as Monterey was colored as occupied by eruptive and metamorphic rocks, while broad belts in the interior, along the courses of the main rivers, were colored as Tertiary. In the edition of 1858 this was in part corrected, the Tertiary being extended to the coast.

The various editions of these maps, on account of the errors mentioned and numerous others perhaps even more inexcusable, though less conspicuous, were severely criticised by American geologists, a particularly harsh review of the 1853 map being given by James Hall in the American Journal of Science for March, 1854, and of that of 1855 by W. P. Blake in the same journal for November, 1856.

The Pacific Railroad Surveys, 1853-1856.

During 1853 numerous expeditions were sent out by the War Department for the purpose of exploring routes for the proposed railroad from the Mississippi Valley to the Pacific coast. These were in all cases under the immediate command of officers of the Army, but to nearly all one or more naturalists or geologists were attached.

The published results of these explorations, geological and otherwise, form the thirteen quarto volumes of Pacific Railroad Reports, so well known to all naturalists. Among those who accompanied the expeditions and whose reports gave almost the first authoritative and systematic accounts of the geology of the regions passed over were Jules Marcou, whose geological map has been mentioned; W. P. Blake, of New Haven, Connecticut; Thomas Antisell, James Schiel, and J. S. Newberry.

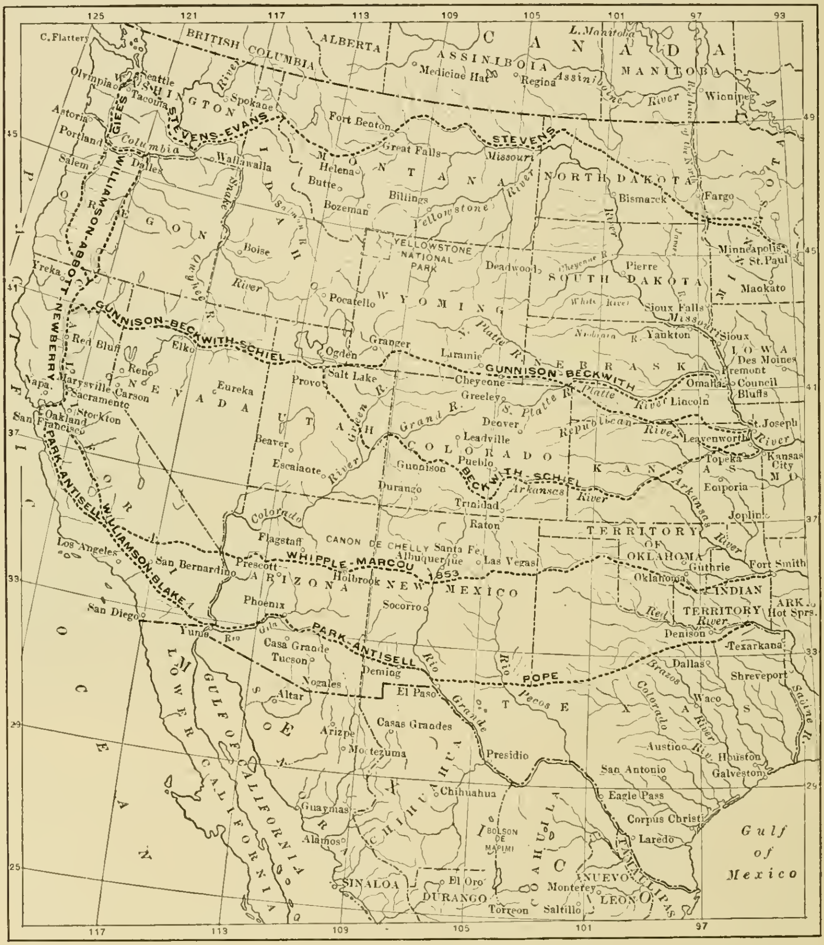


FIG. 59.—Map showing principal routes of exploring parties in connection with Pacific Railroad surveys.

Marcou received his appointment in May, 1853, with orders to join Lieut. A. W. Whipple in the exploration of a route near the thirty-fifth parallel of latitude. The route followed lay by way of Fort Smith, Arkansas; westward through Albuquerque and Santa Fe, New Mexico, to Los Angeles, California, and occupied the period between

June 2, 1853, and March 26, 1854. On returning to Washington, June 1, 1854, Marcou, on the plea of ill health, asked permission to work up his results in Europe; and, acting apparently under a misunderstanding, proceeded to pack his own collections, together with others made by the party under Captain Pope along the thirty-second parallel, and made preparations to leave the country on September 27. This procedure seems, however, to have displeased the then Secretary of War (Jefferson Davis), who insisted, under date of September 25, that the report be made out in this country. It being then too late, as claimed, for Mr. Marcou to change his plans, he was allowed to depart, but instructed under threat of prosecution to turn over all collections and notebooks, the property of the Government, to the accredited representative of the United States at Paris. Naturally this treatment aroused considerable indignation on the part of Marcou, though it is doubtful if he was justified in his subsequent proceedings. Such of the collections and notes as were returned were placed in the hands of W. P. Blake to be worked up, but, while there is no reason for criticising the latter, the report was not all that could have been desired.[a] It is a painful fact, moreover, that none of Marcou's types were returned to America, but were, by him, distributed to English and continental museums, one of the collections being now in the possession of the Geological Society of London.

Marcou's work in Connection with the Pacific Railroad Surveys, 1853.

Before leaving for Europe, however, and before becoming aware of the intentions of the Secretary of War, Marcou made two brief reports or summaries—one of the route traversed by himself, and the other on the materials collected by Captain Pope's party. These were published in House Document No. 129 and were republished, together with other papers by the same author, in Zurich in 1858, under the title of Geology of North America, with Two Reports on the Prairies of Arkansas and Texas, the Rocky Mountains of New Mexico and the Sierra Nevada of California. The latter work was accompanied by a geological map of the United States and a section across the country from Fort Smith to the Pacific Ocean, the same being a reprint of a map published by him in 1855 in the Bulletin of the Geological Society of France and in the Annales des Mines for the same year. (Referred to on p. 449.) It also contained a colored map of an area from 35 to 75 miles in width across New Mexico along the thirty-fifth parallel, bearing date of 1857, and a reproduction of Maclure's map, the original of which bore date of 1809.

In this summary Marcou identified certain horizontal beds overlying the Carboniferous limestones as Triassic, a formation which on the

[a] Marcou's original notes and Blake's translation of the same were published in parallel columns in the third volume of the Pacific Railroad Reports.

basis of his geological map of the United States, published in Boston in 1853, above noted, he claimed to have been the first to recognize in the West. He divided it into three divisions, the lowest of which he considered as equivalent to the red sandstones of Lake Superior (now considered as Cambrian), the Bay of Fundy, the Prince Edward and Magdalen islands, and a part of that of Virginia and New Jersey. At Pyramid Mount, in the Llano Estacado, he claimed to have found Jurassic rocks overlying conformably the Keuper (the first discovery of rocks of this horizon in America), and at Galisteo, in New Mexico, the White Chalk division of the Cretaceous. From the fact that the Cretaceous beds lie unconformably upon the upheaved Triassic and Jurassic beds, he concluded that the same were deposited after the principal dislocation of the Rocky Mountains, which took place at the end of the Jurassic period.

The Sierra Nevada he rightly inferred to be of more recent uplift than the Rocky Mountains, probably dating from the end of the Miocene or Pliocene, and the Coast Range from the end of the Eocene.

FIG. 60.—William Phipps Blake.

Work of W. P. Blake in Connection with the Pacific Railroad Surveys, 1853-1856.

To W. P. Blake fell the lot of accompanying Lieutenant Williamson, whose route led from San Francisco southward along the San Joaquin River, through San Francisco Pass in the mountains to the Mohave River, and eastward along the thirty-second and thirty-third parallels to the mouth of the Gila. The region, as pointed out by S. F. Emmons,[a] "is not one from which definite geological data could be obtained," the rocks, with the exception of recent and Tertiary formations, being barren and classed as metamorphic and eruptive. He however noted the wide-spread occurrence of Tertiary rocks about San Francisco and in southern California and the occurrence of eruptive serpentinous rocks. He also made many interesting minor observations on the polishing and grooving of hard rocks by wind-blown sand and other desert phenomena. Mountains of the isolated or "lost mountain" type were described, and the fact that the Colorado Desert was below the level of the sea noted. The age of the coast mountains was determined as at least post-Pliocene, and the impregnation of the rocks of the region with gold he regarded as having been contemporaneous with the uplift.

[a] Presidential address, Geological Society of Washington, 1896.

To Blake, too, fell the study of the collections made by Pope's expedition along the route near the thirty-second parallel. It was the original intention of Pope that this work should be done by Marcou, but owing to the decision of Davis, then Secretary of War, the collections were returned by Marcou, as already noted, "in a confused condition and with many of the labels displaced" and given to Blake.

Captain Pope's route extended from Preston on the Red River in a southwesterly direction to the Pecos River, and thence nearly due west to the valley of the Rio Grande at El Paso and Dona Ana in New Mexico, crossing the Organ, Huerco, and Guadalupe mountains. The result of this expedition was to establish the Carboniferous character of the limestone of the Organ Mountains, the prevailing granitic type of the Huerco Range, and the presumable Carboniferous age of the limestone and sandstone of the Guadalupes (see also Shumard's observations, p. 434). The underlying formations of the Llano Estacado were judged from the specimens to be probably Cretaceous and not Jurassic, as mapped by Marcou. For the geology of the region between Llano Estacado and Preston, Blake drew largely on Shumard's publications.

The origin of the gypsum beds he regarded as due to the action on the underlying limestone of percolating waters containing sulphuric acid derived from the decomposition of pyrites.

The Work of Antisell.

Thomas Antisell accompanied the party under command of Lieut. J. G. Parke, surveying the route in southern California to connect with the routes near the thirty-fifth and thirty-second parallels and also the route near the thirty-second parallel between the Rio Grande and Pimas Village, which was explored by Parker in 1854–55.

Antisell recognized the post-Miocene age of the final uplift of the Coast Range and thought that the elevating force must have taken place from two points, one in the north and one in the south, and that the forces became gradually spent as they passed, one in a southerly and the other in a northerly direction toward each other. He conceived that this resulted in an uplifting of the consolidated crust of the State at either end, while the center remained quiescent, causing thereby a rupture of the superficial strata, or even a depression below sea level near the middle, forming thus San Francisco Bay.

Influenced to some extent by Elie de Beaumont's theory of mountain uplift and the relative age of mountain ranges, as indicated by their parallelism, he, without committing himself in any way, called attention to the north and south trend of all the New Mexican ranges and northwest and southeast trend of the Sierras, the Coast Range, and the ranges of Nevada.

No Paleozoic rocks were recognized in the southern part of the State. The sandstone underlying the Carboniferous limestone of the

Gila region, New Mexico, was thought to be Devonian, though no fossils were found by which the age might be definitely proven. What fossils were collected during this expedition were described by Conrad and were all Tertiary forms.

As with Hitchcock and other of the early workers, he failed to realize the full capabilities of river action during gradual crustal movement, and found the same difficulty in accounting for the course of the Gila that Hitchcock did with that of the Connecticut (p. 310).

During the series of elevations [he wrote] which finally uplifted this range (the Pinaleno) to its present altitude, the upheaving force must have been exerted even upon the southern portion of the range, raising the table-land of northern Sonora and Chiricahua to so great a height. This strain may have produced a fissure from east to west, or cracked and perhaps depressed the strata along parallel 33°, and thus enabled the Gila to take that as a permanent course. Some such catastrophe must have occurred, for it is scarcely probable that the river unaided could have cut through such lofty hills and hard rocks as it appears to have done in its passage through these mountains, running as it does at right angles to the strike of the ranges.

Antisell's report was accompanied by numerous sections in black and white through the coast ranges, and a colored geological map of the region extending from San Francisco to Los Angeles; also by a colored map and section of the region from the Rio Grande (then known as the Rio Bravo del Norte) to beyond Maricopa Wells (112° 30′).

Fig. 61.—Thomas Antisell.

Sketch of Antisell.

Antisell was born in Ireland, of French Huguenot parentage, in 1817, and came to America for political reasons in 1848, where he practiced medicine until 1854, though in the meantime holding the position of lecturer on chemistry in a number of colleges, including those of Woodstock, Vermont; Pittsfield, Massachusetts; and at the Berkshire Medical Institute. Prior to his American experiences, though by profession a surgeon, he had manifested a lively interest in matters pertaining to other sciences, and had published in 1846 a duodecimo volume of 84 pages on Irish geology and a manual of agricultural chemistry, prepared with especial reference to the soils of Ireland. His work with the Pacific Railroad Survey, above noted, comprised his only geological investigations after coming to America.

In 1856 he was appointed an examiner in the Patent Office, but resigned to enter the Union Army as surgeon in 1861. In 1866 he became chief chemist of the Department of Agriculture, and in 1871 was appointed by the Japanese Government an expert in chemical technology in Tokyo. He returned to the United States in 1877 and was reappointed to his former position in the Patent Office, where he remained until 1891.

J. S. Newberry was geologist to the party under Lieutenants Williamson and Abbot, surveying routes in California and Oregon. Newberry regarded the sandstone in the vicinity of San Francisco as probably Miocene, and the serpentines as of igneous origin—in this agreeing with Blake. The rocks at Arbuckle's diggings, near Fort Reading, were considered as Cretaceous. He did not agree with Trask in thinking that the Sierra Nevada terminated at Lassen's Butte, or that the Coast Mountains, when continued northward, form the Cascades of Oregon and Washington. He regarded Mount Shasta as a part of the Sierra Nevadas (as did also King, later), which were themselves probably of greater antiquity than the Coast Range Mountains. In this he was right. He thought to have discovered evidences of a continuous ice sheet in the region of the Three Sisters and Mount Jefferson in the Cascades. The canyons, as of the Columbia, he rightly regarded as due to stream erosion, not to rifts by volcanic action. The few fossils collected were described by Conrad and all as Miocene.

Newberry's Pacific Railroad Work, 1856.

The survey along the thirty-eighth and forty-first parallels was first placed under the direction of Captain Gunnison, who, however, lost his life in a fight with the Indians in Sevier Lake Valley in 1853. Lieut. E. H. Beckwith was then placed in charge, with Dr. James Schiel as geologist. The route lay across Kansas, up the Arkansas River, and across the front range to the valleys of the Grand and Green rivers, south of Salt Lake; thence across the Humboldt Desert and Sierra Nevadas to the Pitt and Sacramento rivers in California. The report contains scarcely anything of value from a geological standpoint, being mainly mineralogical and lithological, though a few invertebrate fossils are described and one fossil fish, the first named being mainly specimens of *Productus*, *Terebratula*, *Inoceramus*, and *Gryphea*. Nothing was said regarding their probable geological age.

Schiel's Work.

Dr. John Evans, whose early work in the Bad Lands is noted elsewhere, made to Governor I. I. Stevens reports on the geology of the northern route, which were, however, never printed.

Dr. John Evans's Work in Washington and Oregon Territories.

According to Emmons,[a] two reports were made, but both were lost in transit from the Pacific Coast to Washington. No final report was published, though correspondence shows that such was prepared and sent to the Government Printing Office as early as 1861. Doctor Evans dying in 1861, all trace of the manuscript appears to have been lost.

[a] Presidential Address, Geological Society of Washington, 1896.

George Gibbs accompanied a party under the command of Capt. George B. McClellan and made reports on the country lying on Shoalwater Bay and Puget Sound, and also in the central part of what was then the Territory of Washington. His published notes contained little of geological interest. Gibbs, it should be stated, while active in scientific matters, did little work along the broad lines of geology. His bibliography consists, in addition to the above, of three brief notes, altogether comprising less than a printed page. He thought to have discovered that the paving blocks—pebbles—on Waverly Place in New York City had through the weight of traffic yielded as if plastic, so that the concavity of one fitted into a corresponding convexity in its neighbor. He also called attention to the "glades" in Oakland, Allegany County, Maryland, which he believed to have been the seats of ancient glaciers.

George Gibbs's Work in Washington.

FIG. 62.—George Gibbs.

In this connection mention should be made of the survey by Swallow of that portion of the line built under State auspices and extending from St. Louis westward to the State line and known as the Southwest Branch. The report of this survey comprised, all told, less than one hundred pages, and is of interest mainly for the colored geological map of the region traversed. It dealt, naturally, mainly with economic questions, as the distribution of the ores of lead, zinc, and copper and the character of the soil.

Swallow's Survey of the Southwest Branch of the Pacific Railroad in Missouri, 1859.

In 1854 the general assembly of Tennessee passed an act creating for a second time the office of geologist and mineralogist of the State. J. M. Safford, then holding the chair of chemistry, geology, and natural history in the Cumberland University at Lebanon, Tennessee, was appointed to the position, continuing to serve until the outbreak of the civil war, when the work was abandoned. During this time he published two biennial reports, the first in 1856 comprising 164 pages, and the second in 1857 comprising but 11 pages. A final volume on the geology of Tennessee, comprising 550 pages with 7 plates of fossils, appeared in 1869 (see p. 534).

Safford's Work in Tennessee, 1854.

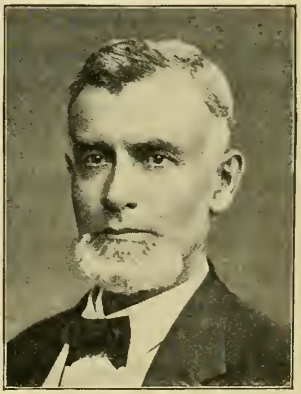


FIG. 63.—James Merrill Safford.

The first report, known under the title of Geological Reconnaissance of Tennessee, was presented to the general assembly in 1855, and published in 1856. It was given up largely to a somewhat popular treatise on the economic geology of the State, with much interesting stratigraphical matter.

He discussed the occurrence of the ores of iron, copper, lead, zinc, and even gold and silver, and included also a brief chapter on Aluminum or the Metal from Clay. "Stone coal" and the marbles received a share of attention, as well as various minor minerals. From a strictly geological standpoint the matter given in chapters 5 and 6—the closing chapters of the report—was of greatest importance. Here he dwelt on the general geological structure of the State and gave the now well-known Cumberland section, reproduced with the original legend in fig. 64, and also an ideal cross section illustrating the geological structure of East Tennessee. He pointed out the striking parallelism of the valleys and ridges and the occasional vertical position of the beds, as well as the frequent repetition of the same series of beds, due to folding and faulting.

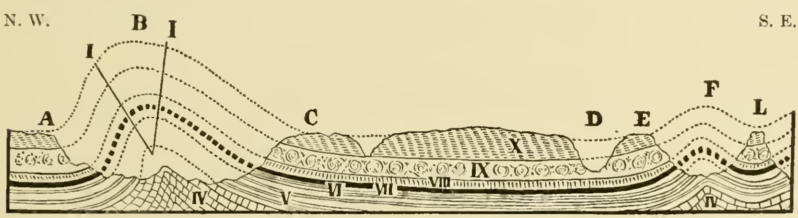


FIG. 64.—Section from the Cumberland, 8 miles north of Jasper, to the Eastern base of Lookout Mountain. (After James M. Safford.)

(Length of section, 20 miles; vertical scale, about five thousand feet to the inch.)

A and C, High edges, respectively, of the Cumberland and Walden's ridge, overlooking Sequatchee Valley, represented by the depression between. D, Narrow valley of the Tennessee River; the section crosses a few miles above Kelly's Ferry. E, Portion of the Walden's ridge and Raccoon range cut off by the river, etc. L, Lookout Mountain. Depression between E and L, Valley of Lookout Creek.

The unbroken lines represent the formations as they actually occur. The broken lines indicate the elevation of the folds, and the amount of matter removed by denudation. B, Summit of the restored Sequatchee fold. I, I, Converging lines indicating a section of the supposed fissure or rent. F, Summit of another smaller fold.

He grouped the rocks under fourteen formations, extending from the mica-slate group of metamorphic rocks of Azoic age to the Alluvial, post-Tertiary series. The much discussed and still enigmatical Ocoee conglomerates were included in his semimetamorphic series at the top of the Azoic. Troost, it will be remembered, put them at the base of his Cambrian.

The importance of fossils for purposes of correlation was at this time distinctly recognized.

Every formation has, in great part, its own species of fossils. Most of those found in one do not occur in any other. Upon this fact depends the great utility of fossils. They furnish, when known well enough to be recognized, unmistakable evidence of the geological position, and hence the general character of the formation in which they occur.

This report shows on the part of Safford a thorough insight into the intricacies of the structure of the State and an ability to grasp the salient features and master the broader problems in a manner perhaps not realized by many of his contemporaries and successors.

The second biennial report, which appeared in 1857, gave simply a brief account of the objects and utility of the survey, with a general summary of what had been accomplished.

R. O. Currey's Sketch of the Geology of Tennessee, 1857.

In this connection Richard O. Currey's Sketch of the Geology of the same State may be mentioned briefly. Currey had been a pupil of Troost and later a professor of chemistry and geology in East Tennessee University. His geological writings are few and limited mainly to such papers as the Southern Journal of Medical and Physical Sciences, the Nashville Banner, and The Virginias. The sketches above referred to were first published in 1853 in the Nashville Banner, and subsequently brought out, under the title quoted, in form of a booklet of 128 pages, accompanied by a reprint of Safford's map in black and white.

Emmons's American Geology, 1854.

In 1854 Dr. Ebenezer Emmons began the publication of a work on American Geology, the intention being, as announced in the "proposals," to bring it out in four or five parts, each of which should contain about 200 pages of matter. The first part, containing 194 pages, was issued at Albany in 1854. It was given up mainly to a discussion of the general principles of geology, of the rocks composing the earth's crust, and some 70 pages devoted to An Application of Geological Facts and Principles to the Business of Mining. Part II—the last that was ever issued—comprised 250 pages and 18 plates, and was given up to an exposition of the author's views on the Taconic and Lower Silurian systems as developed in America and England.

This work, as outlined, was by far the most pretentious of its kind that had thus far appeared in America, antedating Dana's Manual by some ten years, and having for its predecessors only the American reprints of Bakewell's Introduction, Buckland's Bridgewater Treatise, and De La Beche's Manual, besides the smaller text-books of Eaton and Emmons, published in the twenties, and which have been previously noted. There was, therefore, ample room for a work of this nature, but it is doubtful if the occasion was propitious or Emmons the man for the task. Too much of the work (122 pages) was given up to a defense of the author's own peculiar views, which were not in all cases the best, or most generally accepted. His style was poor, often lacking in perspicuity, and in many ways he laid himself open to savage onslaughts of criticism.[a] Unjust as much of this criticism may have been, Emmons, it must be confessed, showed singular ignorance

[a] See Hall's review (unsigned) in the American Journal of Science, XIX, May, 1855.

of, or indifference toward, much of the work that had been done in the West and Northwest, and his ideas regarding the early history of the globe were not the most advanced. Heat was regarded as at first the predominant and active element. As the activity of fire diminished, that of the antagonistic element, water, increased. The first was paroxysmal in its action, the latter constant. In America he found the evidences of aqueous agencies on a grand scale, but "volcanic fire" seemed so far a thing of the past that it was "impossible to obtain specimens even for laboratory illustration."

Fire or heat, he wrote, acts in four ways: (1) In the elevation of areas by expansive forces beneath the crust; (2) by the transferrence of fused matter from the interior to the surface; (3) by producing areas of subsidence, caused by this loss of matter from beneath; and (4) the elevation or depression of areas simply through expansion and contraction of strata by heat and cold. The internal heat he regarded as effective in sustaining "that degree of temperature which is best fitted to the organic and structural conditions of living beings" on the earth.

The classification adopted was essentially the same as that put out in his North Carolina report (p. 431) and need not be repeated here.

The pyrocrystalline rocks, it may be stated, however, he regarded as the results of the primary consolidation of the earth's crust. The fact that some of these occurred in dikes he thought to be due to the fissuring of the earlier-cooled portions of the crust by shrinkage and the forcing up through these fissures of the lower, still unconsolidated portion. He imagined that the age of rocks might be deduced from their crystalline state, the older having been subjected to greater heat and hence becoming most perfectly fused and most highly crystalline on cooling. The granites were, therefore, regarded as the first products of cooling and the oldest of rocks.

Emmons regarded concretions and nodules as symmetrical bodies due to "a force by virtue of which the molecules are really transferred to central points where, by constant accumulation," they form the concretion. The parallel planes of the rhombic forms in limestones and slaty rocks, and jointed structure in general, "admits of the same explanation." The concentric weathering shown by massive rocks was referred to the same cause. Further than this, he regarded the phenomena of rift and grain in a massive rock as identical with cleavage in a simple mineral. Such rocks "are not only composed of crystallized minerals, but they are crystalline in the mass."

The serpentine of Syracuse, New York, he considered a magnesian rock altered by proximity to eruptives, and he still adhered to the idea of the igneous origin of the crystalline limestones of St. Lawrence County, as announced in his New York report. For the first time in an American text-book there was here recognized the relationship existing between conglomerates and sandstones as shore deposits and the pelagic, calcareous, and argillaceous materials laid down at greater depths.

Kitchell's Geological Survey of New Jersey, 1854-1856.

In 1854 Dr. William Kitchell was appointed superintendent of the geological survey of New Jersey. He continued in office until the close of 1856, during which time he made three annual reports, being assisted in the geological work by George H. Cook and in the topographic by Egbert L. Viele. It was expected that Conrad would take charge of the paleontological work, but failing health forcing him to resign, it was placed in the hands of James Hall. Up to the time of the discontinuance of the survey, however, Hall appears to have done little. The vertebrate fossils collected were placed in the hands of Joseph Leidy. Mr. Henry Wurtz served as chemist and mineralogist.

Such part of the work as was done directly by Kitchell contained little that was original or worthy of note, the stratigraphic work being almost wholly done by Professor Cook. In the first report considerable attention was paid to the greenstone marls, their distribution and chemical composition, although other economic questions were taken up, particularly those relating to the iron ores. The magnetic iron ores were regarded as deposited contemporaneously with the sedimentary rocks in which they were inclosed.

In the third annual report, printed in 1856, Cook called attention to the swamp lands and buried timber, and also the apparent gradual encroachments of the sea in Cape May County, and stated it as his opinion that the sinking of the coast was going on at the rate of about 2 feet in one hundred years. The white crystalline limestone of the highlands was here classed as Azoic.

The results of these observations were afterwards printed with some additional matter in separate form, entitled Geology of the County of Cape May, State of New Jersey, bearing the date of 1857. This report contained a colored geological map of the county and catalogues of the zoological and botanical collections and a few fossil invertebrates.

The survey was brought to a close on the 1st of May, 1856, owing to the fact that the State did not feel able to provide an appropriation for its continuance.[a]

Emory's Mexican Boundary Survey, 1855-1856.

The surveying party under Maj. W. H. Emory, for the purpose of fixing the Mexican boundary in accordance with the treaty of 1854, was accompanied by Dr. C. C. Parry in the capacity of geologist and botanist and Arthur Schott as an assistant. The observations made by these two men were largely physiographical and mineralogical, with numerous notes of a lithological nature. Collections of fossils were fortunately made,

[a] According to Cook (Geology of New Jersey, 1868), Kitchell died suddenly in the midst of his active duties, leaving his notes and papers unarranged for publication.

which were referred to Messrs. Hall and Conrad for determination and report. The published report, the work of all the above mentioned, comprised but 174 pages of text, with 21 plates of fossils. It was, however, noteworthy in containing a colored geological map of the Mississippi Valley and country to the west. This has the distinction of being the earliest colored geological map of the region published by the Government. It is, moreover, of historical interest as showing how little was definitely known of the region. The known mountain ranges were colored as metamorphic, often flanked by more or less sinuous, narrow bands of Cretaceous and Carboniferous rocks. Large areas of igneous rocks were represented as occurring in the extreme northwest (California, Oregon, and Washington), but the great interior, the Great Basin region, was left almost entirely blank—geologically a terra incognita.

The fossils, collected largely from Texas, were almost wholly Tertiary, Cretaceous, and Upper Carboniferous forms. A few Lower Silurian forms were figured and named by Hall, but no descriptions were given.

Lesley's Manual of Coal, 1856.

What should have been the most important work on economic geology of the year, and perhaps the most important thus far to appear, with the exception of Whitney's Metallic Wealth of the United States, already noted, was Lesley's Manual of Coal and its Topography, issued in 1856—an octavo volume of 224 pages. The scope of the volume was, however, scarcely what one would be led to expect from its title, and its possible usefulness sadly marred by the personal claims of the author. Not confining himself to the subject of coal and its topography, he entered freely into the subject of mountain structure, with especial reference to the Appalachians, the formation of valleys, theories of the drift, topographical drawing, and kindred subjects. Lesley was, it should be remembered, a topographical assistant on the survey under Rogers in 1839–1851. Reference to his work while on the survey is therefore to be expected, though it must be confessed one's expectations are somewhat exceeded when he lays claim, on his own behalf and that of Messrs. Whelpley and Henderson—also assistants on the Rogers survey—to having been the first to unravel the intricacies of Appalachian structure. "Years of patient toil," he writes, "it cost us to unfold the mysteries of the Pennsylvania and Virginia range." This same claim, in an even more aggressive form, he put forward again three years later, in his Iron Manufacturer's Guide, which appeared under the authority of the American Iron Association, of which he was secretary, in 1859.[a]

[a] These attacks brought forth an emphatic rejoinder from R. E. Rogers (a brother of H. D. Rogers), which was printed privately in form of a pamphlet of 22 pages, 1859.

The merits of the case can not here be decided, but it would seem most probable that this offers but another illustration of the experiences of every executive who has planned, directed, and rendered possible the work of subordinates, only to find in the end that the value of his instrumentality is quite underestimated, and all credit claimed by him to whom opportunity was given.

Dr. Edward Hitchcock's Illustrations of Surface Geology, 1856.

In 1856 Dr. Edward Hitchcock came once more to the front through the medium of the Smithsonian Contributions to Knowledge with a paper of some 150 royal quarto pages and 12 plates. In this he considered all changes which had taken place since the close of the Tertiary period as belonging to the "alluvial formation," and due to causes still in operation. The products of these changes he classed as (1) drift unmodified and (2) drift modified, under the latter including such deposits as beaches, ancient and modern; submarine ridges; sea bottoms; osars; dunes; terraces; deltas, and moraines. The drift proper he regarded as a product of "several agencies—icebergs, glaciers, landslips, and waves of translation"—which, though more active in the past than now, are still at work. The sandy and gravelly plains (the overwash of modern geologists) and the low ridges of New England were thought to represent old sea bottoms, to be "explained only by the former presence of the ocean above them, with its tides and currents."

The terraces of the Connecticut River were described in great detail, with numerous references to those of other regions, both at home and abroad. The chief agency in the formation of these appeared to him, and rightly, to have been water. Moraine terraces, however, demanded the action of stranded icebergs in addition. To account for the drift accumulations at various altitudes, he conceived that the ocean water must have stood some 2,500 feet above its present level. He conceived further "that all the northern part of this continent, at least all east of the Mississippi, had been covered by the ocean since the glacial period," in this agreeing with Agassiz. As to the origin of the material of the "irregular coarse deposit beneath the modified beaches and terraces," he agreed essentially with the German geologist, Naumann, in supposing that: (1) The eroding materials must have been comminuted stone; (2) they must have been borne along under heavy pressure; (3) the moving force must have operated slowly and with prodigious energy, and (4) moving in a nearly uniform direction, though liable to local divergence; (5) the vehicle of the eroded material could not have been water alone, (6) but a firm and heavy mass, somewhat plastic. "Where, now, save in glaciers, icebergs, and ice islands can we find agencies that meet the conditions of the above principles respecting drift?" The exact period of operation of the drift agency naturally he found difficulty in determining. He felt

Fig. 1 Terraces on Westfield River
at the Russell station.

Fig. 2 Bowlders [illegible] Mount T[illegible]
viewed [illegible] the [illegible]

RIVER TERRACES AND DRIFT BOWLDERS IN MASSACHUSETTS.

that while the greater part of the work was accomplished before the continent had emerged very considerably from the water, nevertheless the work of erosion went on for some time after emergence began.

In his discussion relative to traces of ancient glaciers he called attention to the occurrence of two series of striæ, differing in their direction, the more extensive being what he termed "drift striæ," and the second, much more limited in extent, "glacial striæ," the latter being confined to the valleys. The first he thought due to aqueo-glacial causes; the last to glaciers existing earlier than the drift. Further investigation brought to light other striæ which seemed quite as recent as any caused by the drift agency, and he confessed to a feeling of doubt as to which of the agencies was earliest. "Perhaps there were two periods of glaciers, one before and one subsequent to the drift.

The facts concerning the dispersion of bowlders he thought could be more satisfactorily explained by icebergs than by glaciers, since this transportation and scattering continued till after the time when a large part of the beaches and terraces were formed. Glaciers would have plowed tracks through stratified deposits. Icebergs such as now traverse the Atlantic might carry bowlders over the beaches and terraces and drop them from time to time, forming thus the intermixture of coarse, angular blocks and beach or terrace material as we now find it. "The supposition that a glacier once existed on this continent, wide enough to reach from Newfoundland to the Rocky Mountains, is the grand difficulty in the way of the glacial theory." (See further on p. 471.)

The illustrations accompanying this paper were beautifully executed, perhaps the best, both those in color and in black and white, that had thus far been produced.

A second work of Hitchcock, published this same year and needing a brief reference, was his Geology of the Globe, a small octavo volume of 136 pages, 6 plates of fossils, and 2 colored geological maps, one of the United States and Canada and one of the world.

The source of inspiration was evidently Boue's treatise published under the auspices of the Geological Society of France. On the maps the various formations, indicated by color, were: (1) Hypozoic and metamorphic strata, with granite, syenite, and some porphyries; (2) Primary fossiliferous strata to the top of the Carboniferous; (3) Secondary strata; (4) Tertiary strata; (5) Alluvial deposits; and (6) Volcanoes and igneous rocks of the Alluvial and Tertiary periods. Comparatively few areas are left uncolored—areas scarcely larger than those left as unknown or uncertain on the map published in 1884 by the official survey of the United States. When one thinks of this he can but smile at the naive remark of the author when referring to the coloring: "Nor can I doubt that it is done approximately correct."

Such a work was necessarily largely a compilation and contained little original matter.

J. D. Dana, in an article On the Plan of Development in the Geological History of North America, called attention to the fact that the greater mountain ranges border on the greater oceans in both Americas, also to the apparent fact that volcanic activity, or at least the evidence of the action of heat, was greatest along the coasts bordering on the greater oceans.

Dana on the Plan of Development of North America, 1856.

Assuming that the typical form of a continent is a basin with borders of mountains facing the oceans, and the heights of the mountains and volcanic activity are proportional to the size of the oceans, and again that volcanoes characterize oceanic islands and not continental interiors, he showed that the extent and position of oceanic depressions have in a great degree determined the features of the land; that oceanic depression and continental elevation have both been in progress with mutual reaction from the beginning of the earth's refrigeration. The original V-shaped character of the North American continent he showed to be due to the forces acting from the two oceans.

Fig. 65.—Paradoxides harlani.

"Contraction was the power, under Divine Direction, which led to the oscillations of the crust, the varied successions in the strata." These views, it will be observed, are largely in accordance with those advanced in his Wilkes Exploring Expedition report in 1849.

Prior to 1856 the age of the slates of Braintree, Massachusetts, had been problematical. By most of the geologists of the time they had been considered as Primary or, possibly, Transitional. A distinct advance was, therefore, marked when, at the August, 1856, meeting of the Boston Society of Natural History, Prof. W. B. Rogers announced the finding in these slates of trilobites, later identified as belonging to Barrande's Paradoxides and perhaps identical with Green's *Paradoxides harlani*, which had been described from a specimen, source unknown, in the cabinet of Mr. Francis Alger. On presentation of this evidence Rogers felt justified in referring the Braintree slates to the horizon of the lowest Paleozoic group, or about the level of the Primal rocks, the Potsdam sandstone, and the Protozoic sandstone of Owen. The beds, it may be noted, are, in the latest edition of Dana's Manual (1894), referred to the Middle Cambrian, and, therefore, lie below the Potsdam.

The Finding of Paradoxides, 1856.

With the exception of the papers by Dana and Couthouy, scarcely anything of consequence on the subject of corals, geologically considered, had thus far appeared from the pen of an American. At the meeting of the American Association for the Advancement of Science, in 1857, Joseph Le Conte, then professor of chemistry and geology in the University of South Carolina, made his first appearance in the geological arena, with a paper, subsequently published in the American Journal of Science, in which he argued that the peninsula of Florida owed its southern continuation to a double process of coral-reef growth and sedimentation from the Gulf Stream. It was his idea that the sediments brought down by the Mississippi sank to a depth beyond observation before reaching the Keys, but were gradually deposited along the inner side of the curve formed by the current as it passed around the point. When the bottom should have become sufficiently elevated by this process, a new reef would begin to form. This process he thought to have gone on until the channel had become narrowed as now, and the rush of water, together with the depth, practically precluded further deposition. Waves throwing broken material upon the beaches would serve to fill the old channels and convert them into dry land. In brief, "the peninsula and Keys of Florida have been the result of the combined action of at least three agencies. First, the Gulf Stream laid the foundation; upon that corals built up to the water level; and, finally, the work was completed by the waves."

Joseph Le Conte on Coral Growth, 1857.

Le Conte further conceived that the rate of flow of the Gulf Stream has been gradually accelerated by the narrowing of its channel, and hence had made itself manifest at a greater distance into the Atlantic, thus bringing about a gradual amelioration of the climate of England.

In 1855 the first State geological survey of Iowa was organized, and Dr. James Hall made State geologist. The organization continued through 1858. The reports of the survey appeared in the form of two octavo volumes, of which the second volume was given up wholly to paleontology. Hall was assisted in this survey by J. D. Whitney, who served as chemist and mineralogist, and by A. H. Worthen, F. B. Meek, and R. P. Whitfield.

Hall's Geological Survey of Iowa, 1855–1858.

Hall noted the rapid westward thinning out of the various beds of sedimentary rocks, including those of the Hudson River, Medina, Clinton, Niagara, and Onondaga salt group, and Catskill Mountain group, and made the following comment:

> This remarkable fact of the thinning out westerly of all the sedimentary formations points to a cause in the conditions of the ancient ocean, and the currents which transported the great mass of material along certain lines, which became the lines of greatest accumulation of sediments, and consequently present the greatest thickness of strata at the present time. It is this great thickness of strata, whether disturbed and inclined as in the Green and White mountains and the Appalachians generally, or lying horizontally as in the Catskill Mountains, that gives the strong features to the hilly and mountainous country of the East and which gradually dies out as we go westward just in proportion as the strata become attenuated.

Again, with reference to the subdued features of the West, he wrote:

> The thickness of the entire series of sedimentary rocks, no matter how much disturbed and denuded, is not here great enough to produce mountain features.

In this, it will be observed, is given the gist of his theory of mountain formation, as announced two years later.

Numerous changes in nomenclature and important correlations were made, or at least attempted. The Lower Magnesian limestone of Owen he considered as identical with the Calciferous of New York, and gave the name Galena to the limestone immediately succeeding the Trenton, and which Owen had called Upper Magnesian. The "Coralline and Upper Pentamerus beds of the Upper Magnesian limestone," of Owen, he identified as Niagara, and proposed the name Leclaire to designate a gray to whitish limestone lying next above the Niagara and found outcropping near the town of that name. The entire series of Coal Measure rocks he showed to have been deposited after the disturbances producing the low folds in the Silurian rocks, illustrating their relative position by the section here reproduced.

The encrinital group of Burlington and that of Hannibal, Missouri, thought by D. D. Owen to be distinct, were considered by Hall to be identical. The entire series of Carboniferous limestones were regarded as "successively deposited in an ocean, the limits of which were gradually contracted upon the north while at the south the conditions were becoming more and more favorable to the development of this kind of deposition and to the support of the fauna which abounded throughout the period, until both culminated in the great limestone formation of Kaskaskia. (The Archimedes limestone of Owen.)

In discussing the relationship of the limestone and coal, Hall quoted from his report on the geology and paleontology of the Mexican Boundary, elsewhere alluded to. With reference to this he wrote:

> The conditions favorable to the production of an extensive deposit of marine limestone are not such as usually accompany the production of coal. In the present instance the ocean, depositing the great limestone formations previous to the coal period, occupied to a great extent the present area of the Coal Measures which succeeded in the valley of the Mississippi. * * * We begin thus to comprehend the truth, that during the period of the great coal formations of the West, in which these calcareous deposits were in course of formation—that during the oscillations which we know to have occurred throughout the coal period there was a time when the whole area became depressed so as to allow the waters of the western ocean to flow over all the Coal Measure region; or, at least, as far northward and eastward as the northeastern part of Ohio, and from hence it derived the limestone under consideration.

The series of beds immediately underlying the Carboniferous rocks at Burlington, and now considered as Kinderhook (sub-Carboniferous), Hall relegated to the Chemung; this proved to be an error, and one that it required many years to eradicate.

It was noted that the Potsdam sandstone seemed likely to be found strongly developed in the Rocky Mountain region.

Subsequent to this period, however, every sedimentary formation indicates the proximity of land on the east. The great thickness of strata, coarse materials, and numerous fucoids of the Hudson River group in its eastern extension indicate proximity to land, or the course of strong currents, while in the west the formation dies out in some inconspicuous fine shaly and calcareous beds, which, both in nature and condition of the material and in the fossil contents, indicate great distance from land and a quiet ocean.[a]

Hall took the ground that the treeless character of the prairies was due mainly to the character of the soil, and inferred, on what seemed

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[a] The volumes of this work now in the library of the National Museum were the personal property of F. B. Meek, and many of the statements made by Hall are savagely criticised by the former in marginal notes. Thus, with reference to Hall's statements as to the Potsdam, Meek notes: "It was quite safe for him to make this prediction, when he knew at the time he was writing it, I had identified Potsdam fossils in Hayden's collections from the Black Hills. These fossils were then in Professor Hall's house—he had seen them and heard me say I regarded them as Potsdam species."

Still jealous of his discoveries of supposed Permian fossils in the West, Meek also bitterly criticised Hall's reference to the occurrence of Permian and Jurassic rocks in the Rocky Mountain region, and added in the margin: "This was all intended to bear the date of 1857, although every word of it was written after the publication of our (i. e., Meek and Hayden) Permian and Jurassic discoveries in 1858."

Again on page 142, Hall stated: "In the early part of 1857 Mr. Worthen placed in the hands of the writer some peculiar fossils collected several years since in Illinois and supposed to be from the Coal Measures. These, however, were at once recognized as of peculiar forms, differing from Coal-Measure fossils, and a farther examination proves them to be of Permian types, and closely allied to British species." To this statement Meek has added the following marginal note: "At the time he obtained these fossils from Mr. W. he told Mr. W. he regarded them as lower Cretaceous forms." Also "If he had stated when this 'later' examination was made, it would have been all right; but he leaves it to be inferred that it was sometime in 1857, when, in fact, it was not until after the publication of our paper on the Kansas fossils on the 2nd of March, 1858; and yet he intended at that time that this report should bear the date of 1857."

On page 144 Hall suggested the probability of finding in the West beds of the age of the Jura or Oolite of Europe. To this Meek has added the following: "How wonderfully sagacious he was to make this prediction, when he knew we had Jurassic fossils then in his house (which he had seen) from the Black Hills, Nebraska! Yet what is here written is intended to date in 1857."

Again, Hall says: "Thus far the collections made in the explorations across this western country have brought us no true Jurassic fossils, and it is only in the far north and upon the Pacific coast, as well also as in the southern extremity of the continent, that we have the evidences of the existence of these rocks below the Cretaceous formation." To which Meek appended the following: "At the very time when Professor Hall wrote those words some of Doctor Hayden's Jurassic fossils from the Black Hills were lying in a tray within fifteen feet of him, in an adjoining room. I had called his attention to them and told him I was satisfied they must be Jurassic forms."

It is the old story of jealousy and heartburning (warranted in this case, it may be) which seems an almost invariable outcome of any attempt at mutual collaboration.

to him to be reasonable grounds, that the soil itself originated in form of an almost impalpable sediment, which gradually accumulated on the bottom of an immense lake which once occupied the region.

Hall, as already noted, was assisted in his work on the geological survey of Iowa by J. D. Whitney, who served as chemist and mineralogist. A good deal of attention was given by Whitney to the chemical nature of the coals and the distribution and mode of occurrence of the lead and zinc ores. There was, however, very little of a theoretical nature, and speculations regarding the origin of the ores were almost entirely lacking. He regarded the iron ore of Jackson as having originated, in some instances at least, through the decomposition of nodules of iron pyrites which are distributed irregularly through the rock. In other cases he thought it to be a deposit from springs, the original material, however, having been derived from the decomposition of pyrite, as before.

Whitney's Work in Iowa, 1858.

Considerable attention was naturally given to the lead and zinc ores. He noted that where the Galena limestone had a maximum thickness, the lead deposits were limited to the central and lower portions of the rock, and never penetrated the Blue limestone, and he had satisfied himself that, in a great majority of cases at least, the deposits diminished in productiveness rapidly after passing below a limit perhaps fifty feet above the base of the Galena. When, however, the Galena limestone was diminished in thickness, he noted that the lead deposits were found in lower and lower positions until, at last, the bottom of the Blue limestone was reached, where the Upper sandstone entirely cut off the ore, there having never been a single instance, so far as he had ascertained, in which a crevice had been worked in that rock.

He found reason, therefore, to differ somewhat with Owen in his statement to the effect that when a mine was sunk through the Cliff to the Blue limestone beneath, the lodes shrank to insignificance, as considerable deposits of ore had been worked in the Blue limestone, though by far the larger portion of the lead of the upper mines came from the lead-bearing rock.

As to the possibility of the lead-bearing crevices extending downward indefinitely and the probability of deep mining ever being likely to prove profitable, Whitney wrote, "The question can be answered unhesitatingly in the negative," and went on to state that the most profitable method of mining will be in the form of horizontal excavations or drifts and not by means of vertical shafts.

The Iowa lead deposits, it should be noted, he regarded as occurring in gash veins. The mineral deposits of the Northwest in general were classified under the heads of surface deposits, vertical crevices, and flat sheets, as in his work on the metallic wealth of the United States (p. 438).

Perhaps the most peculiar idea advanced by Whitney in any part of his report is that regarding the origin of the siliceous matter of the Potsdam sandstone.

It has been generally assumed that such sandstones were originally formed by mechanical agencies, the material being supposed to have gradually accumulated from the grinding down of previously existing quartzose rocks. The facts collected, however, seem rather to point to chemical than mechanical causes. * * * We can hardly understand how such an amount of quartzose sand could have been accumulated without its containing at the same time a considerable quantity of detritus, which could be recognized as having come from the destruction of the schistose, feldspath, and trappean rocks, which make up the larger portion of the Azoic series wherever it has been examined. The uniform size of the grains of which the sandstone is composed and the tendency to the development of crystalline facets in them are additional facts which suggest the idea of chemical precipitation rather than of mechanical accumulation.[a]

Hitchcock's Geology of Vermont, 1856-1861.

In 1856 Prof. Edward Hitchcock was appointed State geologist of Vermont, and continued to serve until 1860, at which time he submitted his final report, which appeared in 1861 in the form of two quarto volumes of 982 pages, accompanied by a colored geological map of the State, two maps showing the terraces and beaches, and 35 plates of scenery, fossils, sections, etc. Hitchcock was assisted in the work by his sons, Edward Hitchcock, jr., and C. H. Hitchcock, and by Albert D. Hager, in whose charge was placed the final publication of the work.

The main objects of the survey, as outlined in the introduction, were first, to gain such a knowledge of the solid rocks of the State as to be able to delineate them upon maps and sections; second, to study the loose deposits lying upon the solid rocks and trace out the changes which the surface of the State had undergone; third, to collect, arrange, and name specimens of rocks, minerals, and fossils from every part of the State for the State cabinet; fourth, to obtain a full collection, for the same cabinet, of specimens valuable from an economic standpoint; and fifth, to identify the metamorphosed rocks of the State with those which had not been thus changed.

The systematic geology was in immediate charge of Professor Hitchcock, though aided by C. B. Adams, Zadock Thompson, A. D. Hager, and C. H. Hitchcock. The economic geology was in charge of Hager, and the chemistry, of C. H. Hitchcock. The Rev. S. R. Hall aided in the preparation of a report on the northern part of the State and its agricultural possibilities. The paleontological work was done by James Hall, and the paleobotanical by Lesquereux. Hitchcock recognized at this date that each rock formation was characterized by its peculiar group of fossils not found in any other; so that a paleontologist, on seeing a specimen, could usually tell from which of

[a] The explanation of this error lies in the fact that the grains of which this sandstone is made up have been cemented by a secondary deposition of interstitial silica, so deposited as to convert each granule into a more or less perfect crystal, of which the original sand grain forms the nucleus. It is a case of secondary growth and enlargement, a phenomenon now well known to every petrographer, but undreamed of at the time of Whitney's writing.

the series it came, thus indicating a great advance over any of his previous reports.

His views on metamorphism and the production of schistose and slaty cleavage were still, however, in an immature state. It is to be noted, however, that all through his work he is far from being dogmatic, usually contenting himself with a discussion of, and full quotations from, the expressed opinions of others, stating his reasons for adopting or rejecting any one, as the case may have been.

Referring to the agencies of metamorphism, and particularly the chemical changes involved in the "transfer of ingredients from one part of a mass to another," he wrote: "We know of no other agency by which this could be produced, except by galvanism." To the same agency he would ascribe the production of cleavage, foliation, and joints. He nevertheless recognized the possibility of the metamorphism of sediments through pressure, and dwelt in considerable detail upon the elongation and flattening of pebbles in the conglomerates near Newport, Rhode Island. The jointing of rocks in these conglomerates he regarded, as already stated, as due "to some polar force such as heat or galvanism. Mere shrinkage could not have separated the pebbles so smoothly, much less could a strain from beneath have thus fractured them. * * * A mere inspection of the rock in place will satisfy anyone that no mechanical agency is sufficient to explain these phenomena." Yet to-day "mere inspection" will satisfy anyone that mechanical agency is amply sufficient. (See also p. 510.)

He regarded feldspar in all of the crystalline rocks as the result of a process of metamorphism:

> Silicates probably furnished the ingredients, which, being abstracted by hot water, left the excess of silica in the form of quartz, and formed the feldspar and mica to fill up the interstices. The feldspar, which has converted the cement into gneiss, could have no other origin, and this fact, in connection with all the rest which have been adduced, forces a presumption that feldspar in nearly all the crystalline rocks, stratified and unstratified, is a product of metamorphism.

Further on, he wrote:

> Metamorphism furnishes the most plausible theory of the origin of the Azoic stratified rocks, which are mica, talc, and hornblende schists, gneiss, serpentine, white limestone, etc., such as cover a large part of Vermont.

He recognized at this time the influence of water as an essential constituent of the trappean rocks, since the intrusion of the material, often in thin sheets scarcely thicker than writing paper, could not be explained on the theory of fusion from dry heat alone. "By means of water the materials could be introduced wherever that substance could penetrate."

His ideas concerning the origin of the drift had been considerably modified since his earlier reports, though he was not as yet willing to accept the theory of a continental ice sheet. Thus:

We have no doubt that a part of what we call drift phenomena in New England was produced by glaciers such as we have described as once connected with the Green Mountain range. But the main features of drift we impute to icebergs and ice floes as the continent was gradually sinking beneath the ocean.

He thought, too, to have found evidence that the continent went down to a depth of something like 2,000 feet, and as some of the icebergs in the Atlantic have been estimated as extending 2,500 feet below the surface, he argued that the effects of such could not be distinguished from those of glaciers. Indeed, the idea of a continental ice sheet was still beyond his comprehension, and his chief arguments against the glacial origin of much of the drift was based upon the fact that all known glaciers are confined to valleys; and, moreover, that there was no known glacier more than 50 or 60 miles wide, "whereas the ancient American glacier must have been at least 2,500 miles wide and have spread over all the mountains as well as valleys, and often have been obliged to move uphill as well as over a level surface." The three prominent directions of the drift were to him also arguments against the ice sheet. These were essentially the ideas advanced in his Surface Geology (p. 462).

On lithological grounds the alluvial deposits were classified as (1) drift and (2) modified drift, and on chronological grounds into four periods, in each of which the continent was differently situated in respect to the level of the ocean. These were, first, the drift period, when the continent was under water at its greatest depth; second, the beach period, when it began to emerge; third, the terrace period, when the continent rose to nearly its present situation; and, fourth, the historic or present period. The phenomena of the modified drift as terraces and beaches were worked out in detail in this report by C. H. Hitchcock.

In the chapter on hypozoic and paleozoic rocks Hitchcock expressed the belief that the rocks of Vermont have been thrown into a succession of folds while in a semiplastic condition by a force from the direction of the Atlantic, and that their crests have been subsequently denuded, some 10,000 vertical feet having, it was estimated, disappeared from the surface of the Shelburne anticline. The strata of those folds with westerly dips, on the western side of the anticlines, he regarded as occupying a normal position; while those with easterly dips, on the eastern side, had been inverted, so that, as he expressed it, "though we cross an uninterrupted succession of easterly dips in going eastward we can not infer that we are constantly meeting with older and older rocks, and therefore that mere superposition would not justify one in deciding upon their relative ages."

Concerning the position of the much-disputed red-sand rock, Hitchcock remarked that without an exception it rested upon the Hudson River group, and the stratigraphical evidence showed it to be of the age of the Medina sandstone or Oneida conglomerate. In this he was in error, the red-sand rock being now universally conceded as belonging to the Lower Cambrian. He also regarded the black slate beneath the red-sand rock as belonging to the Hudson River group, although Emmons had regarded it as Taconic and thought to recognize a Potsdam sandstone in the vicinity of Whitehall, in this respect antagonizing the views of Adams, as announced in his second report.

The name Æolian limestone was given to the marble beds of Dorset Mountain, which had been renamed Mount Æolius. Its exact geological position was not determined, although it was thought that it might be as new as the Carboniferous.

Hitchcock was inclined to side with Emmons in the Taconic controversy, on the ground that the rocks were physically unlike the Lower Silurian which they underlay and differed in the character of their organic remains. The thickness of these Taconic rocks he estimated to be not less than 25,000 feet.

The clay slate directly overlying the calciferous mica schist was thought to be probably of Devonian age. The calciferous mica schist itself was regarded as having been originally a limestone formation charged with a good deal of silex and with perhaps silicates and organic matter, a great deal of the carbonate of lime having been abstracted by carbonated water and the rock converted by metamorphism into a schist.

The numerous beds of serpentine which were found in the State limits were regarded as having been derived mainly from beds of hornblende schist and diorite. Much of the granite of the State was considered as being as recent, at least, as the Devonian period.

It seems almost extraordinary that, even at this date, there were believed by Hitchcock, as well as by others, to be many well-authenticated instances on record in which toads, snakes, and lizards had been found alive in the solid parts of living trees and in solid rocks, as well as in gravel deep beneath the surface. In these cases it was assumed that the animals "undoubtedly crept into such places while young, and, after having grown, could not get out. Being very tenacious of life and probably obtaining some nourishment occasionally by seizing upon insects that might crawl into their nidus, they might sometimes continue alive even after many years."

Geological Surveys of Wisconsin under Hall, Carr, and Daniels, 1857.

Under date of March, 1857, an act of the Wisconsin legislature provided for a geological and agricultural survey of the State, which was to be under the joint control of James Hall, Ezra S. Carr, and Edward Daniels. This joint leadership seemed, however, to have proven unsatisfactory, and by a second act, approved April 2, 1860, James Hall was appointed principal to the commission. This last organization proved also to be short-lived, the survey being discontinued in 1862, the legislature even going so far as to refuse to refund to Hall the money actually expended by him for the purpose of the survey or to pay for his own services. Under Hall's brief administration Whitney, who had served in a like capacity in Iowa, was employed to complete the work on the lead region and Charles Whittlesey to study the regions lying on the west side of the Menomonee River and the iron region of Lake Superior.

A single royal octavo volume of 455 pages and 9 plates, a colored geological map of the lead region, and a diagram showing the position of the ore crevices, appeared in 1862 as a result of this organization.

In this Hall repeated his attempts at correlation of the western with the eastern formations. In addition he called attention to the driftless area of the State, and to the fact that, over the whole area south of the Wisconsin River, the Galena limestone and a portion of the underlying Blue limestone had been removed by decomposition and solution to a depth of some 350 to 400 vertical feet.

Whitney, in his report on the lead-bearing region showed, as in his previous work (p. 468), that the lead-bearing fissures of the Northwest were limited to one set of strata, and that there are but rarely any evidences of dislocation of the strata or faults. Hence, he was forced to the conclusion that the ore-bearing crevices originated through the action of some local cause or forces which were limited in their field of action to a comparatively narrow vertical range. In short, he conceived the lead-bearing fissures to have been originally closely allied to what are called joints. How far shrinkage and crystalline action may have been concerned in the production of these joints, he was unable to say, but "It will be sufficient at this time to recognize the fact that either or both these causes united would have produced a tension in the mass of rock which would lead to the production of fissures in two different directions." He felt, further, that the direction of the fissures might have been influenced, if not absolutely determined, by an elevatory movement of the region in which they are developed.

He looked upon these veins as having been filled from above, the various metals having been in solution as sulphates in oceanic water at the time of the deposition of the lead-bearing strata, the precipitation as sulphides being brought about through the agency of sulphureted-hydrogen gas, which was liberated by the decomposing organic matter. This is substantially the view held by most authorities to-day. He thought, further, to recognize a general law connecting the lack of mineral deposits in the nonfossiliferous strata with their abundance in those containing organic remains. As in his previous work (Metallic Wealth of United States, p. 438), he differed with both Daniels and Owen as to the metalliferous character of the lower magnesian rocks, thinking it quite improbable that they would be found sufficiently rich in ores to be worked economically.

Richard Owen's Geology of the Globe, 1857.

Whatever may have been Richard Owen's powers as a thinker or teacher, his key to the Geology of the Globe, published in 1857 when professor of geology and chemistry in the University of Tennessee, is beyond question the most extraordinary travesty on geology and geological methods of deduction that has ever emanated from the American press. The fundamental idea seems to have been that there are analogies between organic and world development.

Our planet, perhaps, typifies an ovule from the solar matrix. In its earlier igneous chaotic state it bore analogy to the yet undeveloped amorphous structure of vegetable ovules and the animal ovum. Like them, it had at an early period a nucleus, on which after a time air and moisture deposited additional materials, derived from the matrix. At a later period yet a part of these same materials were carried in mechanical mixture, partly in chemical solution, to promote the development of later formations, forming new continents, etc., just as a portion of the seed (the albumen) and the foodyolk of the egg go to nourish the expanding germ.

The separation of continents typifies the propagation of offshoots, or artificially by cuttings in plants, and seems to resemble the fissiparous mode of reproduction observed among the lowest animals. In some of the earlier cataclysms we have the type of the ruptured Graafian vesicles, while at a final convulsive deluge, the period when the Western Continent and Australia were detached, and when possibly the moon as a terrestrial ovule was thrown into space, we readily recognize the type of ruptured pericarpal dissemination of seed in the vegetable world, of completed incubation and parturition in the animal kingdom. * * *

It is by no means contended that this earth is a monstrous organism, with all the parts and properties of a plant or animal; but simply that in it we have everything developed according to the same laws and plan pervading the rest of creation; that in it we see foreshadowed the type of those future forms and changes which organic bodies undergo by the assimilation of these very inorganic materials.

The idea underlying all these generalizations, which the author claimed to have gained while studying sundry maps spread out on the floor of a vacant room, in order to place before his classes "some great principles of generalization," is that the "formations of the western continent corresponded in many respects to those in the eastern" * * * and "that they must have been detached at some period from each other."

He conceived that "the earth in some of its former geological epochs occupied a smaller volume than before the whole of the present superficies emerged from the ocean and than it did before some of the later successive layers were deposited on the earlier formations." Further, that the original internal nucleus of the earth was of the form of a cube or spherical tetrahedron, and that the rocks of the different successive geological periods will be found less and less dense in structure as they leave the north pole and approach the equator. When these beds were upheaved, "the edges of the formations appear to have been brought to the surface along concentric lines, which are parts of great arches intersecting each other in such a manner as to form equilateral spherical triangles on the earth's surface, each angle or intersection being equidistant from our present north pole." The distribution of coal, the metals, and other mineral products he conceived to correspond with the lines marking these spherical triangles.

The forces which acted in separating the planes above described were supposed to have originated from the internal fluid, materials being thrown into periodical waves by the attraction of the sun and moon, creating thereby electrical disturbances, etc. Indeed, the entire earth he seemed to regard as a gigantic magnet, made so by the heat of the sun.

Before this separation took place the layers composing the South American continent he supposed to have rested on the layers of submerged Africa, Australia to have been superimposed upon Arabia, and North America over a portion of Europe.

Owen further called attention to the fact that, if the north pole were elevated $23\frac{1}{2}^\circ$ above the horizon and the globe then revolved the western coast lines of the chief continental masses would be brought successively to the horizon, proving their parallelism; if depressed to a similar extent the parallelism of the eastern coasts would be similarly proven. In other words, he showed that the coast lines of the continents, as well as of many of the islands, tended to conform to the axis of the ecliptic, and he regarded this angular distance of $23\frac{1}{2}^\circ$, which marks the northward extension of the sun in summer, as a natural unit of measure in the structure of the earth.

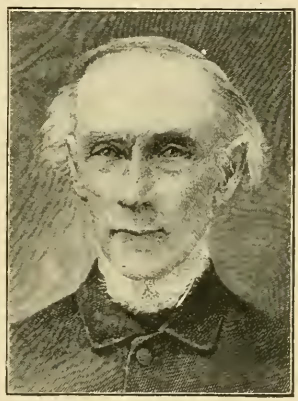

FIG. 66.—Richard Owen.

The book contained a large amount of utterly irrelevant matter, and the above idea and that relating to the possible tetrahedral form of the earth, previously referred to, are the only ones put forward in the work that are to-day worthy of consideration. The book, as a whole, can but impress one as the work of a dreamer, and particularly so when one considers also the amount of irrelevant matter brought forward and the involved character of many of the sentences. Be this as it may, by a peculiar coincidence, at the Montreal meeting of the American Association for the Advancement of Science in August of this same year, Prof. Benjamin Pierce, of the U. S. Coast Survey, brought forward ideas almost identical with Owen's, so far as relates to the parallelism of the coasts, and felt disposed to regard such conditions as evidence that the sun, by influencing in some way the cooling of the crust, had determined the grander outlines.

Owen's ideas regarding the tetrahedral form of the earth, though perhaps original with him, and put forward here for the first time by an American writer, were not wholly new. Those desiring a historical review of the subject, with an account of recent advances and theories, will find the same in a paper by J. W. Gregory, The Plan of the Earth and its Causes, first printed in the Geographical Journal for March, 1899, and reprinted in the Appendix for the Report of the Smithsonian Institution for 1898.[a]

Logan's Proposed Subdivision of the Laurentian, 1857.

At the Montreal meeting of the American Association for the Advancement of Science, for this same year, Logan, referring to previous statements by himself relative to a possible subdivision of Azoic rocks, as given in his annual reports, describes in some detail a series or group of clastic rocks, consisting of siliceous slate and slate conglomerates, holding pebbles of crystalline rocks and sometimes showing ripple marks, which he had traced along the north shore of Lake Huron from Sault Ste. Marie for 120 miles, and which has also been noted in other parts of the Dominion by other observers.

As noted by him on Lake Huron, the formation was some 10,000 feet in thickness and plainly of later age than the gneisses, as well as of distinct lithological character. For this formation he then formally proposed the name Huronian, although the term had been previously used in connection with this formation by Murray in 1848 and Hunt in 1855. To the portion of the Azoic immediately underlying the Huronian he gave the name Laurentian, after the Laurentide Mountains.

At this same meeting he further suggested a possible subdivision of the Laurentian series, in which the calcareous rocks should be considered as distinct from the siliceous. This announcement and the subsequent discussion led to a mass of literature which is perhaps second only to that involved in the Taconic controversy, although, fortunately, without any of its bitterness. Indeed, the entire matter is strongly suggestive of Emmons's Taconic, even if the rocks described could not be accurately relegated thereto.

The principal participants in this discussion, which is even now scarcely at an end, were, aside from Logan, R. D. Irving and Alexander Winchell, though many others took part. Later it was apparently shown that under the name Huronian two distinct formations were comprised, to the older of which A. C. Lawson in 1886 gave the name Keewatin.[b]

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[a] Owen's work was briefly noticed in the American Journal of Sciences. Two or three pages of his matter were quoted, and dismissed with "Remarks on these passages are unnecessary."

[b] For a history of the discussion, see A Last Word with the Laurentian, by Alexander Winchell, Bulletin of the Geological Society of America, II, 1891, pp. 85–124.

During 1857–58 Prof. J. S. Newberry, as geologist, accompanied the corps of topographical engineers, under the immediate direction of Lieut. J. C. Ives, on an expedition up the Colorado River from its mouth to a point called Fortification Rock, north of the thirty-sixth parallel. The main object of the expedition was to ascertain the navigability of the Colorado, with especial reference to its availability for the transportation of supplies to the various military posts in New Mexico and Utah. Newberry entered the country from San Francisco and San Diego, and in Chapters I and II of his report makes reference to the general geology of this part of the region. The party, as above noted, ascended the river as far as the Great Bend, above Black Canyon, and returned thence to the Mojave Valley, south of Pyramid Canyon. Thence the homeward route lay eastward overland to Fort Leavenworth by way of Sitgreaves and Railroad passes in the Black and Cerbat mountains, Bill Williams and the San Francisco mountains, Salt Springs of the Little Colorado, northward to the Moqui Pueblos, and eastward to Fort Defiance, Santa Fe, and Las Vegas (see map). In the latter part of the trip the route lay along that traversed by the surveys for a railroad route to the Pacific under Lieut. Whipple, with which Jules Marcou was connected as geologist. Newberry's report, Part III of the report of Lieutenant Ives, comprised 154 octavo pages, with 3 plates of fossil invertebrates and plants. Made necessarily as a hasty reconnaissance, it nevertheless contains interesting generalities. He rightly regarded the canyon of the Colorado as a canyon of erosion, but conceived that in earlier times the river filled to the brim a series of isolated basins formed by the various mountain chains and interlocking spurs of the synclinal trough through which the river runs, and that during the lapse of ages "the accumulated waters, pouring over the lowest points in the opposing barriers, have cut them down from summit to base," thus forming the canyons. The massive granite walls of Pyramid Canyon, with their capping of stratified gravel, he regarded as conclusive proof of the former existence here of an unbroken barrier "stretching across the course of the Colorado and raising its waters to an elevation of at least 250 feet above their present level." The idea of a possible uplift across the river's course, an uplift so slow as to be counteracted by erosion, as afterward taught by Dutton, was undreamed of, and the mental restorations of past surface contours given are at times startling for their magnitude. Thus, in accounting for the presence of the large bowlders in the gravel of Elephant Head south of the entrance to Black Canyon, with its walls of porphyry from 800 to 1,200 feet in height, he wrote:

The Ives Expedition up the Colorado River, 1857–58.

When the Colorado began the task of cutting down the gigantic wall at the point where its accumulated waters, in greater volume than now, poured down its southwestern declivity, the cascade which it formed must have surpassed any similar exhibition of nature's forces of which we have knowledge at the present day.

On page 42 of his report Newberry gave a section of the Grand Canyon, showing the bottom granite overlain by Potsdam sandstone, and this by Silurian (?), Devonian (?), and Lower Carboniferous (?) rocks, and, finally, Upper Carboniferous limestone. This was the first section of these beds ever published.[a]

The source of the materials which go to make up the sedimentary rocks of the West, he thought, could not have been derived from the emerged surfaces east of the Mississippi, but were rather "formed by the incessant action of the Pacific waves on shores that perhaps for hundreds of miles succumbed to their power, and by broad and rapid rivers which flowed from the mountains and through the fertile valley of a primeval Atlantis." The outlines of the western part of the North American continent, to his mind, were approximately marked out by groups of islands, broad continental surfaces of dry land, and areas of shallow water from the earliest Paleozoic times.

As already noted, a portion of Newberry's return route lay along that previously (in 1853–1854) traversed by Marcou, and it is interesting to note the different views of the two, offered by this opportunity for comparison. Thus Newberry questions Marcou's determination of the age of the formations near Partridge and Cedar creeks, near Bill Williams Mountain, Marcou regarding them as Devonian and Lower Carboniferous (Mountain limestone), while Newberry thought them to be not older than Carboniferous. In like manner Newberry questioned the Permian age of the Canyon Diablo beds, rightly regarding the same as Carboniferous, and the red sandstone overlying this limestone as likely to prove Permian or Triassic. The yellow sandstone along the Rio Grande was considered as not Jurassic, but Cretaceous.

Newberry's Work with the Macomb Expedition, 1859.

In 1859 Newberry again took the field, this time in connection with a topographic party under Capt. J. N. Macomb. The party left Santa Fe, New Mexico, about the middle of July and, crossing the Rio Grande del Norte, followed up the valley of the River Chama, finally leaving it at the dividing ridge between the waters of the Gulf of Mexico and those of the Gulf of California. From here they struck across the headwaters of the San Juan River, passing along the southern base of the Sierra de la Plata, and then northerly to the junction of the Grand and Green rivers. Thence the party proceeded southward to the San Juan River, which they followed up as far as Canyon Largo, passing thence down the valley of the Puerco to the old pueblo of Jemez, and thence easterly back to Santa Fe. The route, it will be perceived, thus covered

[a] This report contains several graphic views of the Colorado Canyon from sketches by F. W. Egloffstein, but which have been largely overlooked since the more recent work of Powell, Dutton, and Holmes.

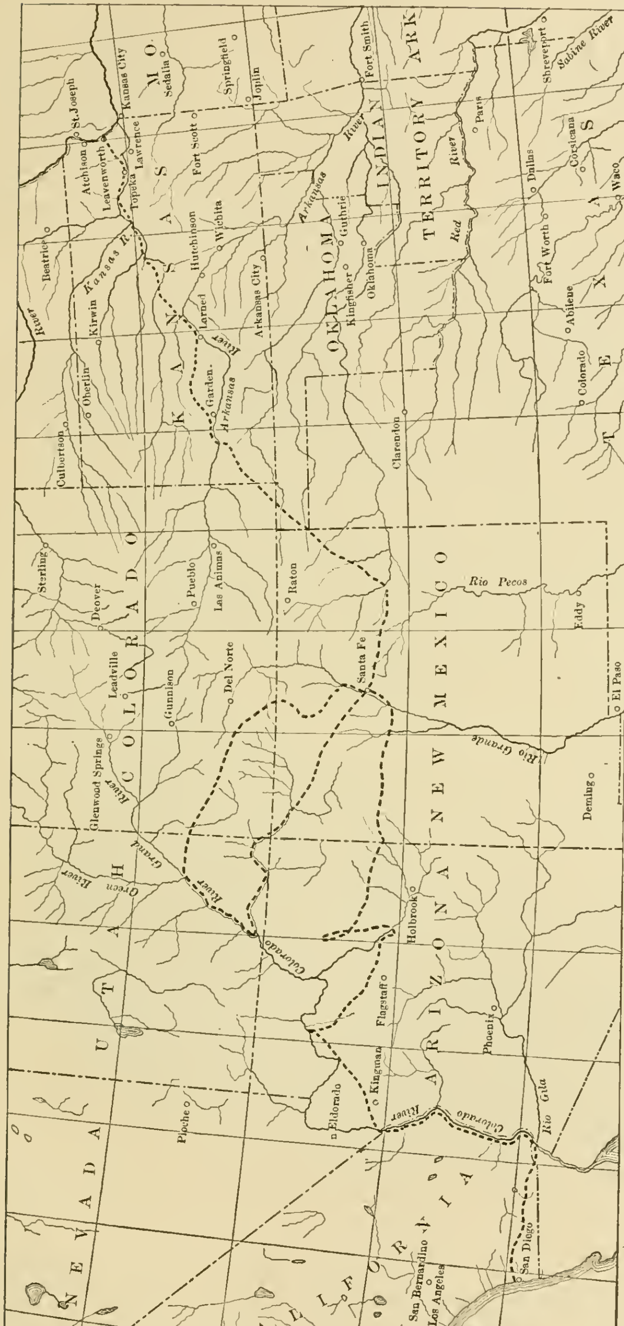


FIG. 67.—Map showing routes traversed by Newberry with Lieutenant Ives and Captain Macomb, 1857–59.

part of the territory previously gone over in connection with the Ives expedition.

The report, though written in 1860, was not published until 1876, owing to the outbreak of the civil war. It comprised an octavo volume of 148 pages, with 8 full-page plates of fossil plants and invertebrates, and a map of the route traversed. Some of the conclusions arrived at during the work of the Ives expedition were confirmed by the more recent work. Perhaps the most interesting of the results as given related to the orographic movements attendant upon the elevation of the Rocky Mountains.

His conclusions were to the effect that—

First. The Rocky Mountains existed in embryo, at least, previous to the deposition of the older Paleozoic rocks, the presence of the upheaved Potsdam sandstone in the Black Hills region showing conclusively that this part of the country was buried beneath the waters of the primeval ocean.

Second. Volcanic activity, which began as early as the Middle Tertiary, continued even into the present epoch.

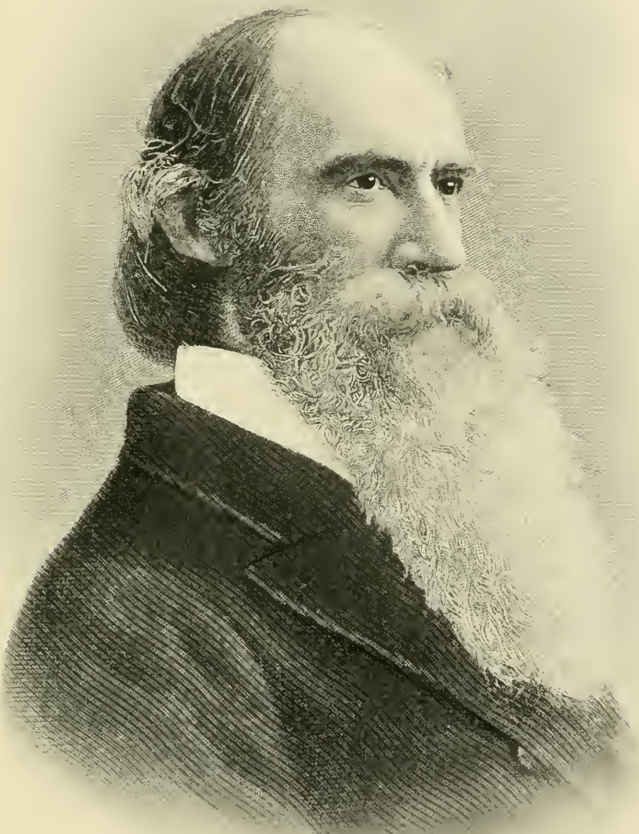
Third. Previous to the deposition of the Lower Cretaceous strata the central portion of the continent was above the ocean level, the main portion of the Cretaceous sediments being deposited during the period in which a subsidence of several thousand feet took place.

Fourth. At the close of the Cretaceous age a period of elevation began, which continued to the drift epoch. This was succeeded by a period of depression and again by one of elevation.

Fifth. The great elevatory movement of the Rocky Mountains took place between the close of the Cretaceous period and that of the Miocene Tertiary.

Sketch of Newberry.

Newberry was born in Connecticut, but his parents moving to Ohio when he was but two years of age, he passed his boyhood in what was then the western frontier. His father, in 1828, then living at Cuyahoga Falls, opened up the coal mines at Tallmadge, making the first systematic attempt at introducing coal for fuel along the lake shore region. The abundant and beautiful fossil flora found in the roof shales of these mines undoubtedly did much toward turning the young man's thoughts toward science, and a visit from James Hall in 1841, while he was but nineteen years of age, still further stimulated his interest. He graduated at the Western Reserve College in 1846, and afterwards studied medicine, receiving the degree of M. D. in 1848. Two years were then passed in study abroad, during which time he made his first scientific publication—a description of a fossil-fish locality at Monte Bolca, Italy. In 1851 he returned to America and began the pursuit of medicine at Cleveland, but although acquiring a large practice he was soon induced to give it up and enter upon a wider field of useful-



JOHN STRONG NEWBERRY.

Professor of Geology, Columbia College, and State Geologist of Ohio.

ness. In 1855 he became connected with Lieut. R. S. Williston's survey in California, and later with that of the Ives Expedition to explore the Colorado, as well as with that of Capt. J. N. Macomb to explore the San Juan region of Colorado and adjacent portions of Arizona, Utah, and New Mexico, as noted. In 1857 he became attached to the Smithsonian Institution in Washington and also accepted a professorship in Columbian University in the same city.

During the civil war he was attached to the Sanitary Commission, and in 1866 became professor of geology and paleontology in the School of Mines of Columbia College, New York, with which institution he remained connected until the time of his death in 1892. In 1869 he assumed charge of the geological survey of Ohio, as noted elsewhere. That the survey, in common with most others of its kind, came to an untimely end was no serious reflection upon Doctor Newberry, though, as his biographer remarks, a mistake was undoubtedly made in postponing the economic portions of the work until the last, and thereby arousing the antagonism of the rural members, one of whom is quoted as having remarked that too much money was devoted to "clams and salamanders." Newberry also did a large amount of paleontological work in connection with the surveys of Illinois, New Jersey, and the United States surveys under Hayden and Powell. His most important works were those in connection with the Illinois and Ohio surveys, and two monographs published by the United States Survey, one on the Paleozoic Fishes of North America, and the other on the Flora of the Amboy Clays of New Jersey, the latter being edited by Dr. Arthur Hollick after Newberry's death.

Newberry is described as a man whose personality inspired confidence in others, though possessing little of what is known as executive ability—a man of kindly, cheerful disposition, and whose desire for fame never went so far as to cause him to assume credit for others work. A pleasing writer and conversationalist and accomplished musician, he made many friends and retained to the end the respect and love of all who knew him.

> His shortcomings were known to his friends as well as were his excellencies; he was impetuous and sometimes he was severe, possibly unjust, in judging men or in dealing with them. But of bitterness he knew little; of forgiveness he knew much. His defects were those of a strong man; in many they would have been sources of weakness, but somehow they seemed to make his friends stand more firmly by him.

Newberry's work received prompt and ready recognition both at home and abroad. He was a charter member of the National Academy of Sciences; foreign correspondent of the London Geological Society, receiving the Murchison medal in 1888; president of the American Association for the Advancement of Science in 1867; president of the New York Academy of Science for twenty-five years; vice-president of the Geological Society of America, and president of the International Congress of Geologists in 1891, although then too ill to attend its meetings.

David Dale and Richard Owen's work in Arkansas, 1857-1860.

April 20, 1857, D. D. Owen, while State geologist of Kentucky, was appointed by the governor of Arkansas geologist of that State, the appointment to take effect "from and after the first day of October, 1857," at which time it was supposed the Kentucky work would be brought to a close. Owen selected for his assistants, E. T. Cox and Leo Lesquereux, with Joseph Lesley, for topographer, and Robert Peter and W. Elderhorst, chemists. Two large octavo volumes, comprising together some 689 pages, were issued in 1858 and 1860, the first having been printed apparently at Little Rock and the second in Philadelphia. They were illustrated with colored lithographs and engravings after originals in Owen's well-known style.

On paleontological evidence the zinc and lead-bearing rock of northwestern Arkansas, i. e., the 300 feet of Magnesian limestone and silicocalcareous rock that underlie the marble strata, forming about 250 to 300 feet of the lower and main body of the ridges of Marion County, were put down as of Lower Silurian age, and as in all probability belonging to that subdivision known as the Calciferous sandrock of the New York system. The "marble limestones" of northwestern Arkansas he was unable to fix definitely, but seemed to think it probable they would prove to represent the Onondaga of New York.

As to the origin of the lead ores, he wrote:

> My impression is that the lead ore once occupied these north and south crevices, and was subsequently removed, in part or in whole, into its present bed by transportation, analogous to that known to mineralogists under the name of the pseudomorphous process, by which one mineral is removed while another takes its place, assuming often the form of the first mineral instead of the usual form belonging to itself. * * * That it should have been deposited like a limestone or sandstone is altogether improbable, and contrary to the usual nature of such ponderous and difficultly soluble minerals.

The cause of the hot springs Owen considered to be the "internal heat of the earth." Not that the waters came actually in "contact with fire," but rather that they were completely permeated with "highly heated vapors and gases which emanate from sources deeper seated than the water itself."

The snowy white novaculite from the vicinity of the hot springs he believed to be of the age of the millstone grit, and "once a simple ordinary sandstone. From the state of ordinary sandrock it has been altered or metamorphosed into this exquisitely fine material, not as I conceive, by contact with fire or igneous rock, but by the permeation of heated alkaline siliceous waters." Through this permeation he conceived that "the particles of solid rock have been gradually changed from grains of quartzose sand to impalpable silica, and the greater part of the oxide of iron, manganese, and other impurities carried out in solution from the pores of the rock, leaving nearly chemically pure silica behind." Such changes are practically inconceivable, and the best authorities to-day regard the novaculites as siliceous replacement of limestone.

A large number of soil analyses were made by Doctor Peter "with a view to settle that very important question" whether such can be of utility to the agriculturist in showing the relative fertility of soils and the loss sustained by cultivation. In Owen's opinion such utility was established "in the most incontrovertible manner."

Owen, it should be noted, died in 1860, and before the publication of the second report, which was brought out under the direction of his brother Richard.[a]

Prof. Lewis Harper, whose work in Mississippi has been already referred to (p. 441), was succeeded as State geologist by E. W. Hilgard, under whose efficient direction there was brought about the first and, thus far, only systematic survey of the entire State. His Report on the Geology and Agriculture of the State of Mississippi appeared in 1860. It contained a systematic and fairly detailed account of the various formations of the State, together with a table of the formations, as shown on next page, the classification and terminology adopted being that of Safford and Tuomey.

Hilgard's Geological Survey of Mississippi, 1857–1860.

[a] According to Branner (Journal of Geology, II, 1894, p. 826) the appropriations for this survey were vigorously combated by some of the legislators, one of whom, in his attempts to defeat the bill, introduced the following amendment:

SEC. 12. The same amount which is appropriated to the State geologist shall likewise be appropriated to a phrenologist, * * * and a like amount to an ornithologist and their several assistants, who shall likewise be appointed by the governor, and shall continue in office fifty-four years * * *; and the secretary of state shall forward one copy of each report to the governor of each State in the Union except such as may be known to be black republican governors; also, one copy to the Queen of England and to the Emperors of France and Russia; also, a copy to the Queen of Spain: provided that government will sell Cuba to the United States on reasonable terms.

SEC. 14. It shall be the duty of the phrenologist to examine and report upon the heads of all the free white male and female citizens in the State, and their children, except such as may refuse to have their heads examined.

Table of the formations of Mississippi.

Name of group.	Principal materials.	Fossils found.
Alluvium	Soils, sand bars, etc	Living plants and animals.
Second bottom	"Hommocks"	(?)
Yellow loam	Brown and yellow brick clays	(?)
Bluff formation	Calcareous silt	Terrestrial, part extinct.
Orange sand	Sands, pebbles, clays	These of underlying formations.
Coast Pliocene?	Black fetid clays	Living marine animals, living trees.
Grand Gulf group	Light-colored clays; white sandstones.	Plants, partly extinct? lignite.
Vicksburg group	Marls and limestones	Marine animals.
Lignitic	Black clays	Plants, lignite.
Jackson group	Marls and soft limestones	Marine animals.
Lignitic	Black clays	Plants, lignite.
Claiborne group	Marls and limestones	Marine animals.
	Siliceous sandstones	Marine animals.
Northern lignitic	Black and gray clays; yellow sands.	Plants, partly extinct; lignite.
Ripley group	Marls and limestones; sandy	
Rotten limestone	Soft chalky likestone, clayey	Marine animals.
Tombigbee sand	Greenish micaceous sands	Marine animals.
Eutaw group	Dark-colored clays; sand	Marine animals; plants, extinct; lignite.
Limestone	Fetid, crystalline limestone	Marine animals.
Sandstone	Siliceous sandstone and chert	Marine animals.
Black slate	Hydraulic limestone	(?)

Fig. 68.—Eugene Waldemar Hilgard.

The Orange sand of Safford was shown to characterize the greater part of the surface of the State, and he regarded it as proved beyond question that its deposition had taken place in floating water, the general direction of the current of which was from north to south. By far the greater portion of the State was shown to be occupied by deposits of Tertiary age, leaving out of consideration the strata of Orange sand which covered a large part of the actual surface.

Hilgard's work had an agricultural bearing and, as may be readily inferred from the work of more recent years both in the Mississippi Valley and California, had to do largely with soils, their original physical and chemical constitution, and methods of rejuvenation.

At a meeting of the St. Louis Academy of Sciences, held on February 18, 1858, Prof. G. C. Swallow presented a paper announcing the finding of Permian fossils among some collections submitted to him for identification by Maj. F. Hawn. This, as being the first apparently authentic announcement of the occurrence of Permian rocks on the American continent, excited a great deal of interest and started a somewhat bitter personal controversy between Hawn, Swallow, and Meek, which may be referred to in some detail.[a]

The Kansas Permian Controversy, 1858.

Hawn, it appears, was a civil engineer engaged in the linear survey of Kansas, but whose interest in matters geological led him to make extensive collections of fossils. These, for purposes of identification, he divided, sending the supposed Cretaceous forms to F. B. Meek, then at Albany, New York, and the Carboniferous to G. C. Swallow, at Columbia, Missouri, the particular collection referred to in this controversy being made at the Smoky Hill Fork of the Kansas River.

The collections received by Meek were of such a character as to lead him to think that the beds from which they were taken might be Triassic or Permian, though perhaps belonging to the Upper Coal Measures. He immediately wrote Hawn, asking that he obtain for him other materials and, if possible, get from Professor Swallow all all of those forwarded to him which were not Carboniferous. To this Hawn readily agreed and wrote as follows:

> Professor Swallow certainly will not attempt to interfere with you in this matter. He knows perfectly well the relation existing between us and expressed himself gratified that I was furnishing you with important information in furtherance of your investigation. Furthermore, he has not the data to establish a relation between the several points under review by you. I merely sent him the Carboniferous fossils for classification and comparison with those of the Missouri collection, that a parallel may be established in my further operations.

Again, under date of September 5, 1857, Hawn wrote to Meek:

> I wrote to Professor Swallow * * * and requested him particularly to send you all the fossils that were not Carboniferous, as they were intended for your use. I hope he will comply with my request, as I shall not have time to go to see him.

And again, under date of September 9, of the same year:

> Should this formation turn out to be as you anticipate, new and important, will you discuss the details in an article for my contemplated work on the mineral and agricultural characteristics of K. T., and describe the fossils that are new?

Under date of January 4, 1858, he wrote again:

> I have a letter before me from Professor Swallow in which he thinks the specimens sent him from Smoky Hill Fork are Carboniferous. Therefore suppose he has

[a] It should be noted that Marcou claimed priority in the discovery of Permian (Dyas) beds in America, the discovery having been made while connected with the Pacific Railroad survey in 1853. (See his American Geological Classification and Nomenclature, Cambridge, 1888.) The correctness of his paleontological identification was questioned by Meek, White, Hall, and Newberry.

not sent you any fossils. Of course, I should not set up my limited knowledge in opposition, but I certainly have forms unknown to me and not occurring in Carboniferous rocks of Missouri which I examined.

Under these conditions it is difficult to understand why Hawn should have later entered into a partnership with Swallow for the working up of the collections and the publication of the results, and it is perhaps not to be wondered at that Meek should have denounced the proceeding somewhat harshly in a paper prepared under the joint auspices of himself and Hayden and read before the Albany Institute on March 2 of that year. Hawn, in a subsequent letter to Meek, excused himself on the ground that Meek's letters had led him to believe that he had abandoned the investigation for want of time or for want of confidence in the final result, and that consequently he brought the matter to the attention of Swallow with the urgent request that the collections be worked up immediately, and at the same time notified him of Meek's suggestion regarding their Permian nature. Swallow himself wrote a very conciliatory note to Meek, which seems, however, to have been far from healing the breach between the parties most concerned.

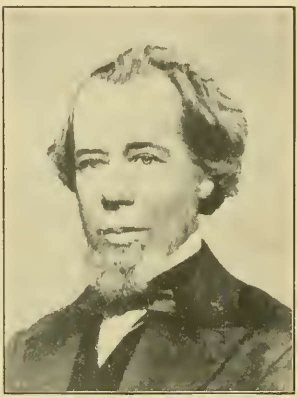


Fig. 69.—Benjamin Franklin Shumard.

The facts of the matter, so far as they can be made out, both from the publications and the letters now in the archives of the Smithsonian Institution, seem to show that, beyond question, Meek was the first to recognize the possible Permian nature of the fossils in question; that he so notified Hawn, and supposed the matter was so arranged that he could work the materials up at his leisure. In the meantime Hawn, as suggested in his letter, thinking that Meek had laid the matter aside, brought it to Swallow's attention, who published the matter with almost unseemly haste in the Transactions,[a] as well as in the local newspapers of the day. In addition, he gave the substance of the discovery in a letter to Dana, dated February 16, which was published as an appendix of the American Journal of Science for March of that same year.[b]

On the 8th of March of this same year B. F. Shumard announced, at the Academy of Sciences at St. Louis, that certain fossils which his

[a] Swallow's paper begins with the following statement, which illustrates his anxiety to claim priority in a discovery, the importance of which was greatly overestimated: "In presenting the following paper to the scientific world, we feel it incumbent upon ourselves to state that it has been prepared in great haste, in the midst of other pressing duties," etc.

[b] Apparently inserted at the last moment before the number was bound up, and too late to be noted in the table of contents.

brother, Dr. G. G. Shumard, had brought from the white limestone of the Guadalupe Mountains of New Mexico were, at least in part, identical with the Permian fossils of Kansas. This is referred to elsewhere (p. 485). Subsequently the supposed Permian was recognized in Illinois by Hall from fossils sent to him by Worthen.

Shumard on Permian in New Mexico.

In the American Journal of Science for May of the year following (1859), Meek and Hayden had a paper on the so-called Triassic rocks of Kansas and Nebraska, in which they expressed the opinion "that the entire series from near the top of the lower Permian of Professor Swallow's and Mr. Hawn's sections, down even lower than the horizon where they draw their line between the Coal Measures and the Permian, should be regarded most nearly related to the Carboniferous and might well be called Permo-Carboniferous." This view for some time prevailed, but recent work has shown that beds, the equivalent of the true European Permean, are present in Kansas, Nebraska, the Guadalupe Mountains, and perhaps in other parts of the West as well.

Meek and Hayden on Triassic in Kansas and Nebraska.

Information regarding the geology of Texas up to this date (1858) had been gradually accumulating through the work of geologists connected with the various exploring expeditions, and more particularly through Ferdinard Roemer's publications. Roemer, it may be well to remark, was a German who came to America in 1845 for the purpose of geological exploration, and passed a year and a half in active work in Texas. The most important of his publications, the outcome of this work, was his Die Kreidebildungen von Texas, und ihre organischen Einschlüsse, Bonn, 1852—a large quarto of 100 pages of text and 11 plates of invertebrate fossils. In 1858 the first attempt at a systematic survey under State auspices was attempted, and Dr. B. F. Shumard, whose paleontological work in connection with explorations under Capt. R. B. Marcy and Colonel Pope have been already noted, was appointed State geologist. Shumard served, through much trial and tribulation, only to 1860, when he was suspended for political reasons,[a] and Dr. Francis M. Moore, who had been one of his assistants, appointed in his place.

B. F. Shumard's Geological Survey of Texas, 1858.

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[a] AUSTIN, *April 5, 1860.*

MY DEAR M.: Your kind letter reached me to-day, and I can not sufficiently thank you for the friendly feeling that prompted you to write it and for the course you have taken in refusing testimonials to the aspirant who desires to supplant me in the place I now occupy. I shall speak to you unreservedly, for I have had too many assurances of your friendship to doubt it. Of the qualifications of the person alluded to, to take charge of a work so important as the survey of this State, I need not inform you. What he knows of geology has not been gathered from study, but from conversations with geologists. Thus he at first made the Coal Measures of Fort Belknap Tertiary and wrote a long article which was published in the Texas papers! He then took some of the same fossils that he relied upon to prove their Tertiary

But one report was issued, a pamphlet of 17 pages, bearing the date 1859. It very briefly outlined the work accomplished, laying considerable emphasis upon the presence of coal and other economic products, including petroleum. George G. Shumard was assistant geologist, W. P. Riddell, chemist, and A. Roessler, draftsman.

Safford on the Unconformability Between the Lower and Upper Silurian Formations in Tennessee, 1858-59.

In a letter to J. D. Dana, and by the latter printed in the American Journal of Science for April, 1858, Professor Safford, then at Cumberland University, Lebanon, Tennessee, called attention to an important and previously unrecognized unconformability existing between the Lower and Upper Silurian formations in Tennessee, indicating, as he felt, the one-time presence of an island some 80 to 90 miles in diameter in the Upper Silurian and Devonian seas, and occupying a central position with reference to the present limits of the State. This he regarded as

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age to the North, submitted them to "my friend Mr. Meek," returned to Texas, and shortly after published a learned (?) article in which he referred these beds to the Coal Measures, their true age. I am aware that he professes to be a friend of mine, but I can cry, "save me from such friends." He says truly that I am or have been in trouble, but all of the trouble has been caused either by himself or his friends. He spent some five or six weeks here last winter during the session of the legislature, and it is believed here that he used every endeavor to get either my position or that of one of my assistants, either of whom are much better geologists than he. Governor Runnels refused him the appointment solely on the ground of incompetency, and insisted, for the same reason, that I should not give him the place of assistant. He has been a politician all his life and for many years edited a leading political paper in this State. No one in this State believes him to be a geologist, although for political reasons some profess to think so. I believe conscientiously that if the geological survey of this State is abolished, it will be done through the maneuvering of Dr. M.'s friends or himself. It would have been abolished last winter had the legislature entertained the opinion that Dr. M. would be placed in charge of the survey. The people throughout the State feel a great interest in the survey. But the important work will assuredly cease with the next legislature if Houston makes the change. I do not know what encouragement Gov. Houston has given Dr. M. He (Houston) has removed every one of Runnel's appointees, except myself, and but for the interference of some of Houston's warmest admirers I should have shared the same fate ere this. I have had indirect assurances from influential Houston men that I am not to be disturbed. It may be, however, that he would like to remove me simply from his hatred to Runnels, and that he would like to shield himself behind testimonials in Dr. M's favor from such men as Professors Henry, Bache, and yourself. Or it may be that Dr. M. wishes the testimonials merely to induce Houston to give him the place. Of one thing I am quite certain, and that is, any testimonials he may succeed in procuring will be employed to the injury of the survey. * * *

I am sorry that I have had to say unkind things of anyone, but in the matter of the Texas survey the case requires it. I shall feel much obliged to you if you will communicate the contents of this letter to Professor Henry, to whom I am under *many* obligations for *many* favors. I shall strive to merit the good opinion that he entertains of me.

* * * * * * *

B. F. Shumard.

probably elevated at the close of the Lower Silurian period and not again depressed until the beginning of the period marked by the deposition of the black shale (Upper Devonian). Later, in 1859, Safford pointed out the fact that the crinoidal and variegated marbles and ferruginous limestones of eastern Tennessee were originally deposited in the form of long, narrow belts, stretching in a northeast and southwest direction entirely across the State. This striking feature he accounted for on the supposition that the materials were deposited in long and narrow troughs, formed by earlier oscillations or corrugations of the earth's crust, the conditions thus confirming the views held by Professor Dana as to the early Silurian age of the beginnings of the Appalachian oscillations.[a]

H. D. Rogers's Final Reports on the Geology of Pennsylvania, 1858.

The geological survey of Pennsylvania, established under H. D. Rogers in 1836, came, it will be remembered, to an untimely end in 1842. Rogers being, however, unwilling to relinquish the work in its unfinished condition, continued it at his own expense until he was able in 1847 to make his final report to the office of the secretary of the Commonwealth. Here, for some unknown reason, the manuscript was allowed to lie until the spring of 1851, when appropriations were made for revising it and bringing it up to date. The appropriations were continued until 1855.

Gross mismanagement of the funds, for which, it is said, Rogers was in no way responsible, prevented the publication of the report, however, and it was not until 1858 that it was finally issued, and then only under a special contract between the author and the State, whereby the latter was to furnish the sum of $16,000 and Rogers was to receive 1,000 copies of the book and the original manuscript. The work was issued by W. Blackwood & Sons, London and Edinburgh, and J. P. Lippincott & Co., of Philadelphia, and was in the form of two quarto volumes containing 1,631 pages, with 23 full page plates, 18 folded sheets of sections, and 778 figures and diagrams in the text.

This was an epoch-making work, and beyond question the most important document on the geology of America that had appeared up to the date of issue, with the possible exception of the final reports of the New York surveys, issued in 1842–43. From these it so differed, however, as to be considered quite by itself. In the New York sur-

[a] These views are again advanced by Ulrich and Schuchert (Report of the New York State Paleontologist for 1901, pp. 633–663), who state that several folds were developed or older ones accentuated at the close of Beekmantown (Calciferous) time. Between these folds of the southern Appalachians during later Lower Siluric times was the "Lenoir Basin," "containing several disconnected longitudinal folds high enough to affect the direction of currents and consequently the character of the sediments, and, in a smaller degree, faunal distribution.' The variegated marbles are in the western or "Knoxville trough" of this basin.

vey stratigraphy based upon organic remains was ever uppermost. In the case of the Rogers reports quite the reverse is true, the physical side preponderating over everything else. While the value of fossils in determining the relative age of strata was recognized, yet out of the entire 1,631 pages but 20 are devoted to invertebrate paleontology and 47—by Lesquereux—to a description and discussion of the fossil flora of the Coal Measures. Naturally, many of the results given in these reports and the opinions expressed had found their way into print several years earlier, particularly through the publication of the American Association of Geologists and Naturalists. Especially was this the case with the results relative to Appalachian structure.

Rogers was aided by a considerable corps of assistants, many of whom afterwards became noted in the same lines of work. In 1836 these were John F. Frazer and James C. Booth; in 1837, Messrs. S. S. Haldeman, A. McKinley, C. B. Trego, and J. D. Whelpley, with Dr. R. E. Rogers as chemist. In 1838 Messrs. H. D. Holl, J. T. Hodge, R. M. Jackson, J. C. McKinney, P. W. Schaeffer, T. Ward, and M. H. Boye were added to the force. In 1839 J. Peter Lesley and Doctor Henderson were added in place of Messrs. Whelpley and McKinney, who resigned. In 1840 the personnel was essentially the same. In 1841 it was reduced to Messrs. McKinley, Holl, Jackson, Lesley, Boye, and Doctor Rogers. In 1851 the geological assistants were Prof. E. Desor and W. B. Rogers, jr., Peter Lesley and A. A. Dalson serving as topographers.

The first volume of these reports treated of the metamorphic rocks and the Paleozoic strata. The second volume began with a discussion of the coal basins of the State, to which over 600 pages were devoted. Some 30 pages were devoted to a discussion of the rocks of the Mesozoic red sandstone series, which was followed by a discussion, first upon the igneous rocks and minerals with special bearing upon their economic value; second, the conditions of the physical geography during the laying down of the Paleozoic strata of the United States; third, the organic remains of the State; fourth, the laws of structure of the more disturbed zones of the earth's crust; fifth, the classification of the several types of petrographic structure illustrated in the Appalachians; sixth, the coal fields of the United States and British provinces, with their chemical and physical characters; seventh, the method of searching for, opening, and mining coal, as pursued in Pennsylvania; eighth, foreign coal fields and coal trade and statistics of the iron trade.

The nonfossiliferous rocks underlying the old Paleozoic were classified as *Hypozoic* or true metamorphic and *Azoic* or semimetamorphic, the Hypozoic including the true gneisses and crystalline schists, and the Azoic or semimetamorphic strata "various coarse talcoid and chloritic schists, semiporphyritic, arenaceous grits and conglomerates, and jaspery and plumbaginous slates," carrying veins and dikes of a metalliferous character.

He recognized the difficulty in at all times separating the Azoic rocks from the overlying genuine Paleozoic, and also the fact that it might at times grade into it without a break. Also he recognized the fact that a portion of his Lower Paleozoic was metamorphic or semimetamorphic. When one reflects on how emphatically Rogers combated Emmons's Taconic system, it seems strange that he should hold to these views.

The belt of metamorphic and semimetamorphic strata extending from Newfoundland to Alabama he designated as the Appalachian or Atlantic Belt, and the one extending westward from the north coast of the St. Lawrence Gulf to the Great Lakes as the Laurentide, owing to the fact that these latter rocks were well developed in the Laurentide Mountains.

The semimetamorphic Azoic rocks he considered as richer in minerals than the true gneisses, and to these he referred the schists of the Atlantic coasts, bearing lead, copper, zinc, and iron, and the auriferous quartz veins of California.

The Paleozoic formation proper, which was estimated to cover probably one-half of the total area of the United States and to have a total thickness of from 30,000 to 35,000 feet, was divided into fifteen distinct series or sets of formations, "extending from the deposits which witnessed the very dawn of life upon the globe to those which saw the close of the long American Paleozoic day." The names assigned to these formations he regarded as "significant of the different natural periods into which the day divides itself, from the earliest dawn to twilight." These were, beginning with the oldest, Primal, Auroral, Matinal, Levant, Surgent, Scalent, Pre-Meridian, Meridian, Post-Meridian, Cadent, Vergent, Ponent, Vespertine, Umbral, and Seral—signifying the Dawn, Daybreak, Morning, Sunrise, Ascending day, High morning, Forenoon, Noon, Afternoon, Waning day, Descending day, Sunset, Evening, Dusk, and Nightfall. These terms, based on time, he considered preferable to the inexpressive ones, mainly of a geographic character, then in vogue.

The Primal, Auroral, and Matinal were regarded as the approximate representatives of Sedgwick's Cambrian; the Levant, Surgent, Scalent, and Pre-Meridian, near representatives of the English Silurian, beginning with the Upper Caradoc Sandstones. He recognized both a physical and paleontological break in the succession of strata at the contact of these two great divisions of the Paleozoic system. At the base of the Carboniferous he thought to recognize a break correspondingly sharp.

The entire Paleozoic system was thus divided into three natural divisions, as follows:

Upper Paleozoic	Seral	Carboniferous	Coal Measures.
	Umbral		Middle Carboniferous
	Vespertine		Lower Carboniferous.
Middle Paleozoic	Ponent	Latter Devonian and Carboniferous.	Catskill.
	Vergent		Chemung and Portage.
	Cadent		Genesee, Hamilton, and Marcellus.
	Post-Meridian	Older Devonian	Upper Helderberg.
	Meridian		Oriskany.
	Pre-Meridian	Silurian	Lower Helderberg.
	Scalent		Onondaga Salt Group and Niagara Limestone.
	Surgent		Clinton.
	Levant		Medina.
Lower Paleozoic	Matinal	Cambrian	Trenton Limestone, Utica and Hudson River slates.
	Auroral		Black River, Chazy limestone, and Calciferous sandstone.
	Primal		Potsdam.

The sediments making up these Paleozoic strata were, according to his views, derived from a land area now occupied by the Tertiary seaboard plain and the waters of the Atlantic Ocean. This deposition was preceded by a wide movement of depression, which began in the south or southwest and permitted the waters of the Appalachian sea to occupy what is now the upper half of the southern Atlantic slope. There was, however, left above water to the southeast of the present Atlantic plain, a large tract of continent or great chain of islands which, with numerous fluctuations in their limits, remained as such down to the close of the Carboniferous period.

He considered it as "susceptible of demonstration that the various coal basins, bituminous and anthracitic, of Pennsylvania, Maryland, Ohio, Virginia, Kentucky, and Tennessee were originally united," "the whole as one great formation." This is essentially the view held to-day. The structure of the coal, as he viewed it, rendered "it apparent that no irregular dispersion of the vegetable matter by any conceivable mode of drifting * * * could produce the phenomena which they exhibit," and he could not conceive of "any state of the surface adapted to account for these appearances, 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 leaves on the marsh." In this he agreed with Beaumont, though his evidence was of different character. He further believed that the coal material became finally engulfed through earthquake action, the sea receding and then returning once more laden with detritus, carrying everything before it and reaching far inland. Thus the entire marginal forest growth might be uprooted and as the sea again retreated the material would be spread broadcast and mixed with coarse rock detritus. When finally the earthquake paroxysms ceased and the sea became quiet, the fine silt in suspension was deposited, forming thus the soil for another growth.

The regular decrease in the amount of volatile bituminous matter in the coal as one passes from west to east was accredited to the action of 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. The coal in the east basin would thus be effectually steamed, and raised in temperature in every part of the mass would discharge its bituminous matter in proportion to the energy of the disturbance.

Rogers, it should be noted, found in the American Carboniferous no recognizable base defined by organic remains alone, and in his classification relied mainly on the suddenness of the change from marine to terrestrial forms and the rapid appearance of that amazing vegetation characteristic of the coal period.

He conceived the Connecticut red sandstone as having been deposited on sloping shores within a narrow estuary, its greatest depth near its eastern margin, the material itself having been derived from the west. The sandstone west of the Hudson in New York State he believed to have been deposited in an estuary having its greatest depth to the northwest, the materials being derived from the southeast. The period, he argued, was ushered in by a sudden agitation of the region, resulting in an abrupt depression of the tidal portions of each tract below the general ocean level. Into these depressions the suddenly displaced drainage would drop a lot of fragmentary material such as would form the lower lying conglomerates. Finer materials brought in later by stream action, and more or less modified by tides, formed the upper beds. He agreed with Emmons in regarding these Mesozoic sands as of Jurassic and Oolitic age.

One of the most important chapters in the work related to types of orographic structure and the physical structure of the Appalachian chain, which was worked out in conjunction with his brother, Prof. William B. Rogers. This formed the substance of a paper read before the Association of American Geologists at its third session in April, 1842, and already noted under that date (see p. 370). It is well to recall, however, that, under the title of *Dislocation of an Anticlinal Axis Plane—Uninverted Side of Wave Shored Over the Inverted*, he described and illustrated the overthrust faults of the modern geologist, and remarked on their misleading character, owing to the resulting dipping of younger strata beneath those which are older.

The origin of valleys occupying the crests of anticlinal ridges, which he designated as "valleys of elevation," he rightly described as due to the carving force of waters. The mountains themselves he thought to have been elevated by successive but sudden earthquake movements through and above the ocean; the water of which, as a consequence, was propelled in gigantic billows and rushing sheets transversely across the anticlinal ridges, scooping them out where weakest into the form of terraced oval valleys.

Slaty cleavage was looked upon as due not to movement, purely, but to the action of heat waves traversing the rocks. In proof of this, he cited his observations to the effect that, in gneisses lying in an undisturbed horizontal position, the foliation is almost invariably coincident with the stratification, the heat producing it having flowed upward, invading stratum after stratum. Where granite occurs invading gneissic strata, the foliation, according to his views, is parallel to the plane of outflowing heat. He thought to discover two general laws: First, that the planes of foliation "are parallel to the waves of heat which have been transmitted through the strata," and second, "the foliation is parallel or approximately so to the cleavage, when both occur in the same rock mass.

A singular and, to the present writer, unaccountable discrepancy in the work of Rogers lies in his almost completely ignoring the latest glacial views as advocated by Agassiz and others. The fact that the greater part of the work was completed and the manuscript prepared prior to 1848 can scarcely be considered a sufficient reason, since the years 1851–1855 were devoted to its revision and bringing it up to date. Moreover, his mention of the fact that the marine Pleistocene formation of Canada had been designated Laurentian clays by Desor (in 1850), shows that he was at least conversant with the literature of the period; the fact that he had considered, if not fully comprehended, Agassiz's views, is shown by a brief paragraph, in which he described and figured drift striæ seen on an exposed surface of Umbral sandstone on the south side of the Wyoming Valley. These are described as pointing up the slope toward the southwest, "as if produced by fragmentary débris violently propelled against the sloping mountain wall of the valley from the north." The presence of such ascending striæ, both here and elsewhere, effectually refuted, according to his conception of it, the glacial theory of their origin. Like Hitchcock, he failed to conceive of other than local mountain glaciers of the Swiss type. Without mentioning the name of Agassiz or other of his collaborators than that of Desor, he gave the following, even then antiquated matter, after a general discussion of the distribution of the drift and the various phenomena accompanying it. For the earlier drift, it should be noted, he offered no explanation whatever other than implied in a reference to a period of repose which "separated the convulsed epochs of the earlier general and later local drift."

A ready explanation of the origin of this newest Pleistocene deposit (i. e., that of the Hudson and Lake Champlain districts) suggests itself when we consider the nature and energy of the crust movements which lifted the Laurentian clays and sands to a height, in one locality at least, of not less than 500 feet, and which drained wide tracts of the Upper Laurentian lakes. The mere agitation or pulsating movement of the crust, if unaccompanied by any permanent uplift of the land, would suffice we would think, by lashing the waters of the tidal estuaries in one quarter and the lakes in the other, to strew a portion of the older drift bordering all those basins in wide dispersion upon the top of the more tranquil sediments; but if such a pulsation of the crust were accompanied with successive paroxysmal liftings of wide tracts of the land, then the inundation would take the form of stupendous currents, the strewing power of which would be adequate to any amount of superficial transportation, even to the remote transportation of the larger erratics.

His ideas regarding vein formation and the origin of quartzite were equally crude. Thus, speculating on the wide distribution of the Potsdam sandstone, its remarkable uniformity and purely quartzose nature, he wrote with particular reference to the last:

May we not conjecture that this * * * was supplied from the great dikes and veins of auriferous quartz, which * * * issued in a melted condition through the rents and fissures of the crust over all the region of the Atlantic slope. * * * Outgushing bodies of this quartz mingled with volcanic steam, and suddenly chilled and pelted upon by cold and heavy rains, may have been granulated into sand, as would occur with heated unannealed glass, and then washed in copious streams into broad, shallow, and tide-moved sea, and there gradually dispersed and precipitated.

From the above it will appear that Rogers was a catastrophist. Further than that, viewed in the light of to-day, many of the conclusions which he drew from observed phenomena and the theories advanced are strikingly absurd for a man of his learning. This is particularly true with reference to his ideas on the formation of anthracite (p. 372), the origin of valleys (p. 493) and mountain chains (p. 371), and that of the Potsdam sandstone just mentioned. Indeed, his entire work well illustrates the peculiar, uneven make-up (if I may be allowed the expression) of some of our best workers. Gifted with a mind unequaled for power of observation and deduction, he was yet wholly deficient in theory.[a] "Great men, of great gifts you shall easily find, but symmetrical men, never."

[a] The work was favorably reviewed in the American Journal of Science for November, 1859, almost the only unfavorable criticism relating to the deficiency of paleontological work and the geological nomenclature adopted. "The author has left this great department (of paleontology) of the survey to future workers. This being so, the author has hardly a broad enough basis for the institution of a new system of nomenclature and of subdivisions for the Paleozoic formations, and especially for diverging in these respects from the New York survey, in which the subdivisions had been founded upon a thorough study of the organic remains. The names of these subdivisions, Auroral, Matinal, Levant, Surgent, and so on, can not be proved to be better than those before adopted. They are founded on the idea of a Paleozoic day, which has had no existence except in the fancy of the writer. This unfortunate framework, about which Professor Rogers has clustered his facts, is no serious impediment to the geological reader who has a key at hand for comparison.

The work is a great one, worthy of the State which authorized the survey. It contains a vast amount of information in all its departments, and will ever rank among the most important of the reports of the geology of the United States.

As previously noted (p. 433), J. G. Norwood, State geologist of Illinois, was succeeded in 1858 by Amos H. Worthen. Under the latter's direction the survey lasted until 1875, when active field work was discontinued, owing apparently to an indisposition on the part of the legislature to provide the necessary funds. Six volumes of reports had been issued up to this time, and by the aid of subsequent special appropriations, two more were completed, the last bearing the date 1890, and on the title page the name of Joshua Lindahl, State geologist, and Worthen as director. The total published results of this survey amounted to upward of 4,000 pages of text and 197 full-page plates of fossils.

Amos H. Worthen's Work in Illinois, 1858-1875.

Worthen was aided at various times during the work by J. D. Whitney, Leo Lesquereux, Henry Engelmann, J. S. Newberry, F. B. Meek, H. C. Freeman, H. M. Bannister, H. A. Green, James Shaw, G. C. Broadhead, Orestes St. John, and E. T. Cox. The work of Whitney naturally related to the mining problems of the State, Lesquereux to the paleobotany, Meek to the invertebrate paleontology, Newberry to the vertebrate paleontology, and the others mentioned to general stratigraphy.

In the first volume of his work Worthen divided the sub-Carboniferous into five groups: The Chester, St. Louis, Keokuk, Burlington, and Kinderhook, the term Chester group being used in place of the Kaskaskia of Hall, and the St. Louis including the Warsaw of Hall. The blue, green, and chocolate-colored shales immediately underlying the Kinderhook group in western and southern Illinois he regarded as Devonian.

Whitney, in his report, regarded the Galena limestone as the "sole depository of lead in western Illinois," a view not quite in agreement with that expressed with reference to the Iowa and Wisconsin fields. Two maps were given in this report—one a geological map of the northwest corner of the State, and the other showing a diagram of the lead-bearing crevices near Galena. The origin of these lead-bearing crevices "seems to be the same cause by which what are called joints by geologists have been formed in almost every variety of rock, occurring in large homogeneous masses, and especially where a decided crystalline texture exists in them." The course of the main set of fissures he thought might have been determined by the axis of upheaval, by which the whole region had been slowly elevated along the north boundary of the district, the metals themselves having been held in solution in oceanic waters and precipitated through the agency of decomposing organic matter.[a]

[a] This is essentially the view held to-day, with this difference: Most geologists believe that the ore was originally disseminated throughout the limestone, and that it has become segregated in veins and pockets through the leaching action of meteoric waters.

Lesquereux, in connection with his paleobotanical work, took occasion to announce his adherence to the view that the coals were the result of the accumulation of sphagnous mosses, in place, i. e., were not drift. He also introduced a chapter on the origin of prairies, in which he took the ground "that all the prairies of the Mississippi Valley were formed through the slow recession of sheets of water of varying extent, whereby the existing lakes were gradually transformed into swamps and bogs and ultimately into dry land. The black surface soil of the prairies he thought to be due to the growth and decomposition of bog vegetation, confervæ, etc." With this view Worthen, in the fifth volume of the reports, did not wholly agree. No one theory, he thought, was sufficient to explain all the phenomena noted, though the chief cause of the treelessness of the prairies he felt to be due to the character of the soil itself. The loess Worthen regarded as of fluviatile origin. Concerning the origin of the drift as a whole, he wrote:

> Thus it will be seen that the first and greatest of the drift forces was the glacier; then the floating iceberg and ice field produced their results, carrying the large bowlders from place to place and dropping them over the ice-cold seas; and lastly, the wave and current force of water, after the ice had in part or altogether melted, leaving the loose clays, sands, and subsoils, substantially as we find them.

In his second report, published in 1866, Worthen adhered to the determination first published in the Transactions of the Philadelphia Academy of Sciences, 1865, to call by the name of the Cincinnati group the rocks of the State grouped by Hall under the name of Hudson River. This volume was devoted wholly to the paleontology of the State, and contained articles by Newberry, Meek, Worthen, and Lesquereux. Newberry, in his work on the fossil fishes, accounted for the abundance of some of these forms in certain strata as due perhaps to the sudden introduction of "heated waters or noxious gases" in the Carboniferous seas where these forms lived.

The third volume appeared in 1868, and was given up to a discussion of the geology of the various counties, with paleontology by Meek and Worthen.

The fourth volume appeared in 1870. It was devoted quite largely to paleobotany by Lesquereux, vertebrate paleontology by Newberry and Worthen, and descriptive geology of the various counties by Worthen, Bannister, Bradley, and Green.

Sketch of Worthen.

Worthen was born in Vermont in 1813, and educated in the common schools and the local academy. In 1834 he emigrated to Kentucky, and in 1836 removed thence to Warsaw, Illinois, where he made his permanent home. Until 1855 he was engaged in mercantile pursuits, but devoted all his spare time to a study of the local geology, to which he was attracted by the abundant fossil remains for which the region was noted.

At the time he began his work satisfactory text-books were few and the difficulties which he encountered in addition may be best understood when it is remembered that work was undertaken more than fifty years ago, when railroads were practically unknown, when postage on a single letter cost 25 cents, and when, moreover, money was scarce and labor cheap. There being no overland freight or express lines, all his exchanges of specimens with friends in the East were made by means of Mississippi River steamboats between Warsaw and New Orleans, and Gulf of Mexico and Atlantic sailing vessels between New Orleans and Boston. Often months would elapse between the time of his sendings and return of exchange material.

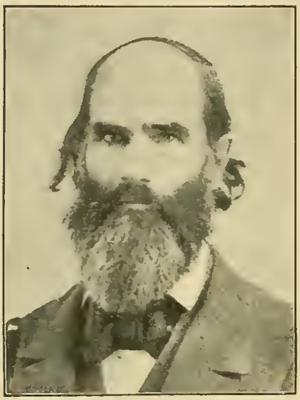
Fig. 70.—Amos Henry Worthen.

In 1851 Worthen first began attendance upon the meetings of the American Association, and in 1853, as noted, took part in the survey of the State of Illinois, under the direction of J. G. Norwood. From 1855–1857 he was assistant to James Hall on the survey of Iowa, and in 1858 was made State geologist of Illinois in place of Norwood, as already mentioned.

Worthen's own labors related principally to the Carboniferous rocks, and to him belongs the credit of being the first to work out the true relations of the divisions of the Lower Carboniferous system in this section.

Personally, as we are told by his biographer, Worthen was of manly presence, kindly, candid, and of unpretentious manner, impulsive and generous to his friends, charitable even to those with whom he had little sympathy, but uncompromising in his love of justice and scientific truth. His thorough interest in his work is shown by his persistent continuation of the same under the most adverse conditions. Again and again his work was in danger of suspension by the threatened failure of the necessary appropriations by the legislature, and more than once they were so far reduced that only the most careful management averted disaster. Once during 1875–1877 the appropriations were allowed to entirely fail, but he continued his work without compensation and with such sincerity of purpose that they were resumed by the next legislature.

Lesquereux, whose paleobotanical work has been on several occasions described in these pages, and to whom we shall again have occasion to refer, was born at Fleurier, Switzerland, in 1806, and came to America with Arnold Guyot, about 1848. His early scientific studies were on living plants; but later, and particularly after coming to America, he turned his attention almost exclusively to fossil forms. His work on the coal plants of Ohio, Pennsylvania, Illinois, and

Arkansas began in 1850, and his papers appear in the geological survey reports of all these States. His work on the coal flora of Pennsylvania was particularly valuable, forming what was at the time the most important work on Carboniferous plants published in America. Lesquereux became early connected with the Hayden surveys, and to the time of his death, in 1889, was actively engaged in the study of the materials collected by members of this organization. Deaf from early manhood, a foreigner, with but poor command of English, he labored under enormous disadvantages. To an interviewer he once remarked:

Sketch of Lesquereux.

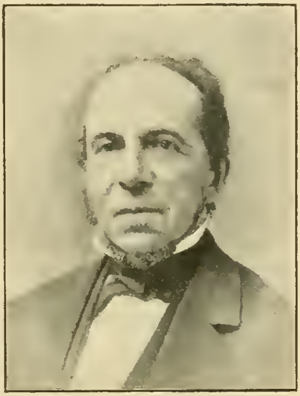

FIG. 71.—Leo Lesquereux.

> The science student's life is absorbed with grave and serious truths; they are naturally serious men. My associations have been almost entirely of a scientific nature. My deafness cut me off from everything that lay outside of science. I have lived with nature, the rocks, the trees, the flowers. They know me. I know them. All outside are dead to me.

In April, 1858, Henry Youle Hind, of Toronto, was authorized by the provincial government of Canada to explore the region "lying to the west of Lake Winnipeg and Red River, and embraced (or nearly so) between the rivers Saskatchewan and Assiniboine, as far west as South Branch House on the former river." He was directed further to procure all the information in his power respecting the geology, natural history, topography, and meteorology of the region. The work was accomplished between June 14 and October 31, the results being published in 1859 in form of a thin quarto volume of 201 pages, with a colored geological map, two plates of fossils, and other maps, figures, and sections. The region was described as occupied by Laurentian gneisses to the east of Lake Winnipeg, succeeded to the west by Silurian, Devonian, and Cretaceous formations. The Cretaceous fossils were described by F. B. Meek and the Devonian and Silurian forms by E. Billings.

Hind's Work in the Winnipeg Country, 1858.

Hall's principal contribution to strictly physical geology was that relating to the accumulation of sediments and the formation of mountain chains. The first brief announcement of this was made in his reports on the geology of Iowa, (p. 465). In 1857 he brought the matter before the public once more in his address before the American Association for the Advancement of Science, at Montreal. This address was, however, not printed at the time, and it was not until two years later that he

Hall's Views on Sedimentation and Mountain Building, 1859.

formulated his views and gave them in extension in part six of the third volume of the Natural History of New York. In 1869, in an address on the Geological History of the North American Continent, delivered before the American Institute of New York, he reiterated many of the opinions previously announced, and, finally, in 1882 brought out the original address of 1857, and this, it is said, without revision. Whatever changes or additions it was found desirable to make were added in the form of supplementary notes. The subject may, therefore, be conveniently reviewed at this date (1859).

Hall had shown that one simple and intelligible sequence of strata, from the Potsdam sandstone to the end of the Coal Measures, covered, with slight exceptions, the entire country from the Atlantic slopes to the base of the Rocky Mountains, and that while the horizontal strata gave their whole elevation to the highest parts of the plain, the same beds were folded and contorted in the mountain region, thus giving to the mountain elevation not one-sixth of their actual thickness. He thought to have shown conclusively that the line of greatest accumulation of sediments had been along the direction of the Appalachian chain; in other words, that the Appalachian chain was itself due to the original deposition of materials and not to any subsequent action or influence breaking up and dislocating the strata of which it was composed.

Discussing the cause of this folding and plication, he referred to the fact previously recognized by Herschel to the effect that sea bottoms, when loaded by accumulated sediments, undergo a process of subsidence which may cause an elevation of the adjacent continental areas, a principle which was then becoming generally recognized and which has since become known under the name of *isostacy*. When, then, these sediments were spread along a belt of sea bottom, as originally in the line of the present Appalachian chain, the first effect would be to produce a yielding of the earth's crust beneath and a gradual subsidence. Evidence of this subsidence was furnished by the great amount of material accumulated, for it was impossible, he argued, to suppose that the sea had been originally as deep as the thickness of the accumulations (some 40,000 feet).

The line of greatest depression would, therefore, be along the lines of greatest accumulation. By such a process of subsidence the lower side of the accumulations would become gradually curved and stretched, and there would follow, as a sequence, rents and fractures. On the surface above, which would be contracted horizontally by such subsidence, there would be produced wrinkles and foldings of the strata. Into the rifts formed below it was conceivable there might rush fluid or semifluid material, producing what are now evident as trap dikes.

The sinking of the mass would produce a great synclinal axis, and within this axis, whether on a large or small scale, would be produced numerous smaller synclinal and anticlinal axes. The greater amount of compression above or stretching below along the line of maximum thickness of the sediments would account for the gradual decline toward the margin of the major syncline or the evidences of fracture and distortion. This, he thought, afforded a partial explanation of the fact that mountain elevations in disturbed regions bear, in their altitude, a much smaller proportion to the actual thickness of the formation than do the hills in undisturbed regions; and, further, that since in the formation of an anticline the beds are weakest at the ridge and become more liable to denudation, such are often worn down to form low ground or even deep valleys, while the synclinal arches, being protected in the downward curvings of the beds, may remain to form the prominent mountain crests, as is observable in the southern Appalachians. It nowhere seemed to him that folding or plication had contributed to the altitude of the mountains, but rather that the more extreme the plication the greater had been the general degradation of the mass wherever subjected to denuding agencies.

The chief elevation of the Appalachian chain, he argued, was continental and not of local origin, and the present mountain barriers to him were but the visible evidences of the deposits upon an ancient ocean bed, while the determining cause of their elevation existed long anterior to the production of the mountains themselves.

At no point nor along any line between the Appalachian and Rocky Mountains could the same forces have produced a mountain chain, because the materials of accumulation were insufficient, and though we may trace what appears to be the gradual subsiding influences of these forces, it is simply in these instances due to the paucity of the material upon which to exhibit its effects.

Referring to the amount of metamorphism which these rocks had undergone, Hall thought that we must look to some other agency than heat for the production of the phenomena, and that the "prime cause must have existed within the material itself; that the entire change was due to motion or fermentation and pressure aided by a moderate increase of temperature, producing chemical change." Just what is meant by this it is difficult to say, but, inasmuch as Hall seems to have been in consultation with Sterry Hunt, it is safe to assume that it was intended to include all possible causes which future investigation might show to have been operative.

These views of Hall seem not to have been favorably received at first by the American geologists, and were facetiously referred to by Dana as proposing a system of mountain making with mountains left out. To this Hall very justly replied that he had not intended to offer any new theory of elevation, nor to propound any principle as involved beyond what had been suggested by Babbage and Herschel. What he did intend to imply was that mountain elevation was due to sedimentary accumulation and subsequent continental elevation.

Hunt, coming to Hall's assistance, argued that his views were largely in harmony with those previously maintained by masters in the science of geology, de Montlosier, as early as 1832, having declared that the great mountain chains of Europe were but the remains of continental elevations which had been cut away by denudation, the foldings and inversions in the structure of mountains being looked upon as local and accidental.

Joseph Le Conte, in a later paper, was inclined to criticise Hall's theory as insufficient, but a statement of his views, as well as those of Dana, may be left to their proper place in chronological succession.

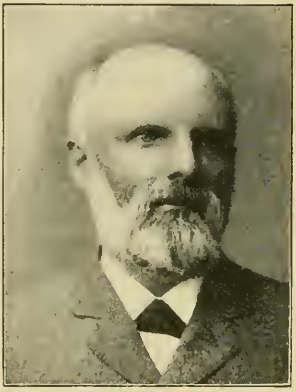

Fig. 72.—Henry Engelmann.

Engelmann's Work in Utah, 1859.

In 1859 Henry Engelmann accompanied, as geologist, an expedition commanded by Capt. J. H. Simpson, organized for the purpose of opening new wagon routes for military purposes across the Great Basin of Utah. Engelmann's report, accompanied by one of Meek's on the invertebrate fossils, formed Appendixes I and K of the general report of the expedition. Originally, as it would appear from the text, the manuscript was accompanied by a geological map and profile, though such do not seem to have been published. No explanation is offered, but it is probable that developments during the long interval up to time of publication[a] were such as to make the map of doubtful value, and it was suppressed. Engelmann's observations began with the country in the immediate vicinity of Leavenworth. He noted the presence of rocks of Carboniferous and Permo-Carboniferous ages along the Republican River, and of Cretaceous and Tertiary deposits farther west. In the district leading from the eastern foothills of the Rocky Mountains to the divide between the waters of the Atlantic and Pacific he thought to recognize rocks of Silurian and probably Devonian, Carboniferous, Permian, Triassic, Jurassic, Cretaceous, and Tertiary ages.

[a] Owing to the outbreak of the civil war, the publication of the report was delayed until 1876.

CHAPTER VI.

THE ERA OF STATE SURVEYS, FOURTH DECADE, 1860–1869.

The period of the civil war might naturally be expected to be a period of uncertainty and inaction in matters relating to the sciences. In all the seceding States work then in progress was brought abruptly to a close, and in several of them—as Missouri, North Carolina, and Texas—the records so far lost or ruined through neglect as to make them well-nigh valueless for future reference. Throughout the North the results were comparatively less disastrous, though even there work was in some instances temporarily discontinued, owing to the failure of legislatures to make the necessary appropriations. In four instances, however (California, Indiana, Maine, and New Jersey), surveys were established almost in the midst of the threatened disaster.

With the passing of these years of turmoil, active work was begun once more in States where it had been but temporarily suspended, and in others, new organizations authorized, as in Kansas in 1864, Iowa and North Carolina in 1866, and Louisiana, Michigan, and Ohio in 1869. A futile and ill-considered attempt at a State survey of Nevada was also made in 1866 (?), but, fortunately for the reputation both of the science and the individual, no one was found to undertake the work under the conditions proposed.[a] W. E. Logan continued his work as provincial geologist of Canada, and Murray and Richardson were employed in Newfoundland.

The literature of the decade was scarcely as voluminous as in either the preceding or the one following. By far the most important, when all is taken into consideration, was the first edition of Dana's Manual of Geology—a work of 798 pages, which at once took its place as the leading authority on all matters pertaining to American Geology—a place which it has continued to hold through all its four editions down to the present. In addition to this may be mentioned Logan's summation of the geology of Canada (1863) and Cooke's New Jersey (1868).

This was largely an era of new workers, or, at least, new leaders. Eaton was gone; D. D. Owen died at its very beginning; the elder Hitchcock had largely ceased his labors; while the Rogers brothers had both become absorbed in the work of teaching and administration, and no longer took an active part. Dana was undoubtedly the leading

[a] The sum of $6,000 is stated to have been appropriated, with the stipulation that the survey be completed in eight months.

figure, while James Hall, by sheer physical energy, dominated in matters paleontological. Many new names and faces appear. Among them may be mentioned those of T. B. Brooks, E. Billings, Robert Bell, E. T. Cox, E. D. Cope, F. V. Hayden, C. H. Hitchcock, W. C. Kerr, W. E. Logan, Alexander Murray, J. G. Norwood, Edward Orton, R. Pumpelly, C. Rominger, N. S. Shaler, C. A. White, and Charles Whittlesey.

As a whole, the decade was one of extension of the geographic boundaries of knowledge rather than one of discovery or announcement of new principles. Of all subjects, that of glaciation received, perhaps, the most attention. Our line of separation between this and the decade to follow must be quite arbitrary, since several important surveys were organized during 1869 and continued well on into the seventies.

R. Thomassy's Practical Geology of Louisiana, 1860.

At the very beginning of this era there appeared R. Thomassy's Geologie Pratique de la Louisiane, a small quarto volume of 263 pages, with 6 plates. Why the word "pratique" should have been introduced into the title it is hard to say, a large proportion of the work being given up to geographical and meteorological or physiographical matters, and the really geological portion limited to a description and discussion of the lower Mississippi, its delta, and attendant phenomena. Its appearance seems to have excited little interest, not being even noted in the American Journal of Science, and the few original ideas advanced are referred to by Hilgard and other subsequent writers only to show their erroneous nature.

Thomassy dwelt in considerable detail upon the absorption of the waters of the Mississippi by the porous terranes above New Orleans and their consequent diminution in volume seaward. The "mud lumps," so common in the lower reaches of the river, he regarded as due to mud springs, having their source at a somewhat higher level on the land and opening upward in the bed of the stream.

He considered North Island, or Petite Anse, as it is more commonly known, as of volcanic origin, and thought to have discovered traces of the violent corrosive action of thermal waters and acids on the rock fragments which he conceived to have been ejected from the depths of the Gulf through explosive action. Richard Owen, it may be mentioned, while serving in the Federal Army and stationed at New Iberia, Louisiana, studied these deposits cursorily, and came to the conclusion that the island was not volcanic. On the contrary, he thought the salt was the product of evaporation of modern sea water, forming lagoons behind protecting ridges under the influence of occasional high tides. (See also Hilgard's views, p. 561.)

In 1859, largely through the efforts of Alexander Winchell, then professor of physics and civil engineering in the State University,

ALEXANDER WINCHELL.

Professor of Geology and Paleontology, University of Michigan, and State Geologist of Michigan.

there was established a geological survey of Michigan. Of this Winchell was appointed director, making his first Report of Progress—an octavo volume of 339 pages—in 1861. In this report he called attention to the futility of efforts then being made to produce salt in the vicinity of Grand Rapids, and fully anticipated the development of the same industry in the Saginaw Valley, his explorations enabling him to locate the salt beds at a depth of 650 feet. Attention was given, also, to the occurrence of gypsum, coal, iron, and other economic products and to the geographical distribution of rocks belonging to the various formations throughout the State.

Winchell's Work in Michigan, 1859–1861.

The so-called Marshall sandstone (Lower Carboniferous) he regarded on paleontological grounds as lying above the Hamilton group. He found evidence which led him to conclude that the Ohio and Michigan coal basins were never continuous, as had been heretofore asserted, and, indeed, that the geological column in the latter State had been built up quite distinct and independently from that in adjacent regions. He could find no parallelism between the Carboniferous limestones and those lying farther to the west, and all the evidence indicated to him that these deposits were laid down in an isolated basin cut off from that of Ohio to the south throughout the entire period from the Helderberg to that of the drift. In consequence of the outbreak of the civil war no appropriations were made for the continuation of the survey after 1861.

Winchell was born in the town of Northeast, Dutchess County, New York, in 1824, and graduated at Wesleyan University, Middletown, Connecticut, in 1847. His scientific tendencies are said to have manifested themselves at a very early age, although he showed no marked preference for any branch of study, unless it was toward mathematics, in which pursuit he seems to have been little short of precocious. Immediately after graduating he entered upon a career of teaching and lecturing, which kept him prominently before the public for over forty years.

Sketch of Winchell.

His first public geological lectures were given at Pennington Seminary in 1849. In 1850 he assumed charge of an academy at Newbern, Alabama, but finding the conditions were not what he had been led to expect, he resigned, and in the spring of 1851 opened the Mesopotamia Female Seminary at Eutaw, in the same State. Finding, however, that he was illy adapted to the successful management of a Southern female institution, he gave up this position to accept the presidency of the Masonic University at Selma, Alabama. While engaged in the work of presenting the claims of this university before the people in the southern part of the State, he made extensive geological tours throughout the region and brought together large collections in natural history. In November, 1853, he was elected to the chair of physics and civil engineering in the University of Michigan, at Ann Arbor, and entered upon his duties in January, 1854.

In 1859 he was commissioned by Governor Moses Wisner, of Michigan, as State geologist, as above noted, holding the position for two years, when the survey was abolished through failure on the part of the legislature to make proper provisions for its continuance. He issued while holding this office one Report of Progress, an octavo volume of 339 pages, published in August, 1861. In 1869 the survey was reorganized and Winchell again appointed director, he assuming for himself the personal investigation of the lower peninsula. His report, a small octavo volume of 64 pages, appeared in 1871, the previous report on the Grand Traverse region, a work of 97 octavo pages, having appeared in 1866.

Owing to hostility over the management of the survey, which had been aroused in the legislature by personal enemies of Winchell, it appeared likely that the appropriations for carrying on the survey would fail. Hence he resigned the position in 1871.

In 1873 Winchell resigned also his professorship at the University of Michigan, accepting the position of chancellor of Syracuse University, which he held, however, only until June, 1875. In this latter year he was offered the professorship of geology, zoology, and botany in Vanderbilt University, at Nashville, Tennessee, but did not see fit to accept, although he did subsequently fill a three months' engagement there. In May, 1878, he took final leave of the university, and the chair was abolished, owing to some foolish differences of opinion that had arisen between himself and Bishop McTyeire, who took exception to Winchell's stand in reference to pre-Adamites and evolution.

In June, 1879, Winchell was again called to Ann Arbor, being offered the chair of geology and paleontology in the State University. This position he accepted and continued to hold until the time of his death. In March, 1887, he was offered the position of State geologist of Arkansas, but refused.

Winchell's work as a geologist, as may be readily imagined from this sketch, was of a more or less fragmentary nature, and it is as a teacher, public lecturer, and writer on scientific subjects that he is best known. The advanced stand which he took regarding evolution brought him in conflict with the religious element, particularly at Vanderbilt University, as already referred to.

Winchell was for a time connected with the Minnesota geological survey. He was one of the original promoters of the American Geologist and the Geological Society of America. As stated by his biographer:

His largest educational field, however, was the public platform. Here he was under no constraint by reason of youthful auditors. No limits were set to his rhapsodic scientific eloquence; no courteous regard for the amenities of possible professorial etiquette hampered the free flow of his criticism, or the exultant prophecy of the betterments of the future. * * * Himself a working geologist in the field, he was well acquainted with geological methods. A teaching geologist in the university, he was skillful in imparting his own knowledge and in training others to habits of observation and investigation.

As a writer of books Winchell will be remembered for his Sketches of Creation, 1870; the Doctrine of Evolution, 1874; Pre-Adamites, 1880; Sparks from a Geologist's Hammer, 1881; World Life, 1883, and his text-book, Elements of Geology, 1886. Of these his work on World Life is undoubtedly the one showing the greatest amount of research and thought, and was at that time probably the only one in the English language covering in a systematic manner the entire field of world history.

Work of D. D. and Richard Owen in Indiana, 1859–1862.

In 1859 D. D. Owen had, for the second time, accepted an appointment as State geologist of Indiana, but with the stipulation that, until his surveys in Arkansas and Kentucky, upon which he was then engaged, were completed, most of the field work should be performed by his brother Richard. Owing, however, to Doctor Owen's death in 1860, the work fell wholly upon the brother, who succeeded him in the office of State geologist.

The results of the survey are comprised in an octavo volume of 364 pages, issued in 1862. Like other of this author's writings, it is prolix and uninteresting, differing in this respect in a marked degree from those of David Dale.

The importance of fossils was recognized, and it was set down as an "unquestioned truth that a certain vertical range or ascertained thickness of fossiliferous rock is characterized by the organic remains of plants and animals, differing more or less from the plants and animals in the rocks above as well as those in the rocks below the given layers or strata." The rocks of the State were all classified under: (1) Lower Silurian; (2) Upper Silurian; (3) Devonian; (4) Subcarboniferous; (5) Coal Measures, and (6) the Drift or Quaternary. Some 25 pages were given up to soil analyses by Robert Peter, and 70 to a report on the Distribution of the Geological Strata in the Coal Measures of the State, by Leo Lesquereux

No maps or sections accompanied the report, which, as a whole, is singularly lacking in interesting or instructive matter. J. Lesley served as topographer.

With the outbreak of the civil war Owen resigned to take command of a company of volunteers, and this, the third attempt at a geological survey of Indiana, came to an end.

Prevailing ideas regarding conditions of sedimentation have been frequently referred to in these pages, but with more particular reference to the position of the sea floor—whether inclined or horizontal—upon which the sedimentary beds were deposited. A new phase of the question was brought to light during a discussion between W. B. Rogers and

Louis Agassiz at the meeting of the Boston Society of Natural History, March 21, 1860.

Rogers argued that the strata between Lake Ontario and the Pennsylvania coal region were deposited on gradually subsiding sea bottoms. On this supposition only could he account for the relative position of the beds and their very great thickness. Had they been formed as argued by some on a gradually rising sea bottom, the older deposits would crop out at the higher levels and the successively later ones at lower levels. Agassiz, on the other hand, maintained that there was no subsidence during the deposition of the New York strata, and that the facts indicated just the reverse, i. e., an upheaval. During the upheaval, he argued, the level of the sea might be actually less, from the contraction of the earth while cooling, but in consequence of this contraction the ocean would always remain at a certain depth, sufficient for the deposition of the thousands of feet of strata. The study of the fossils he argued was also opposed to the theory of subsidence and denudation, since those of the Primary were never found carried into the Secondary beds.

Ideas of Rogers and Agassiz on Subsidence and Deposition, 1860.

At the April 4 meeting the discussion was resumed, when Rogers took the ground that an assumption of an upward movement of the sea bottom carried with it the admission of an original depth so enormous as to be incompatible with the accumulation of the material of the earlier strata, unless, indeed, the strata were supposed to be formed exclusively within a moderate distance of the shore.

We might imagine a series of strata to be successively laid down in a gentle slope approximately parallel to that of the ancient sea bottom, each terminating against this surface without being continued into the profounder depths beyond, and we might suppose the floor to be rising in the region of this accumulation at such a rate as to bring successive tracts, farther and farther from the ancient shore line, within limits of depth admitting of mechanical and organic deposition; but in such circumstances of formation these earlier strata, instead of extending, as they are believed to do, almost continuously over the whole ocean floor, would be seen to determinate at no great distance from the original shore line, but abutting against the bottom at the places where the depth had set a limit to their accumulation.

No hypothesis of a secular rising of the sea bottom, he therefore argued, could explain the formation of the Appalachian Paleozoic deposit. They indicated, rather, a long period of subsidence of the ocean floor, varied by many and long pauses of upward oscillations.

Agassiz, in reply, admitted the probable shallowness of the ocean in which the strata were deposited, and that during a local upheaval of the shore, the whole sea bottom was probably subsiding, the subsidence being due to shrinkage, caused by the cooling of the earth's crust. This view was accepted by Rogers as amounting to a virtual disclaiming of the theory as advanced.

The removal of B. F. Shumard as State geologist of Texas in 1860, as noted on page 487, was immediately followed by the appointment of his successor, Dr. Francis Moore, "an honorable and cultured gentleman of much executive ability," a one-time newspaper editor, but, so far as can be learned, never a geologist.[a]

Work of Moore and Buckley in Texas, 1860-1864.

In April, 1861, the survey was, however, suspended by an act of the legislature, and both Shumard and Moore requested to report on what had been accomplished. With this request neither party complied, Shumard going immediately to St. Louis, where he died in 1869, and Doctor Moore leaving for the north on the outbreak of the civil war, where he, too, died in 1864.

The notes of these short-lived organizations seem to have, in part at least, passed into the hands of S. B. Buckley, a botanical collector under the Shumard régime, who returned to Austin after the close of the war and succeeded in having himself appointed State geologist. In this capacity he issued one report, bearing date of 1866, and comprising some 80 octavo pages, dealing with generalities and matters pertaining to the agricultural resources of the State, but containing little or nothing of geological value and but few references to what had been done by his predecessors. Buckley's period of rule was short, coming to an end in 1867.

No attempt at resuscitation was made until 1870, when the governor, under authority from the legislature, appointed John W. Glenn State geologist. Glenn, however, found the position uncongenial and resigned the following year, to be succeeded in 1874 by Buckley once more. The latter held the office but two years, when the governor, becoming convinced (truthfully, it is to be feared) that the survey promised to be of no practical benefit to the State, vetoed the bill appropriating moneys for its continuation.

J. W. Glenn appointed State Geologist of Texas, 1870.

During this second term of office Buckley issued two reports, under dates of 1874 and 1876, respectively, comprising altogether some 220 pages. The first contained a brief history of the past surveys of the State and a somewhat partisan account of an unhappy disagreement

[a] AUSTIN, *November 12, 1860.*

MY DEAR M.: Your kind letter reached Austin during my absence from home, and I thank you for your friendly words. I returned yesterday from the Indian country, and only then found I had been superseded by Doctor Moore in the office I held. Houston had not even intimated to me that he intended my removal. So far as I can learn, the action of the governor has caused universal dissatisfaction. I am not even permitted to make out my own reports of more than two years' hard labor. I understand that my removal has been brought about mainly through testimonials furnished Moore by H. and H.

If I had had timely notice, so that I could have written my report, I should not have cared so much, but to be deprived of that privilege is doing me great injustice.

I have not made any plans for the future. When I have a little more leisure I will write you again, and then may furnish you with some geology that may interest you.

In haste, your friend, B. F. SHUMARD.

which existed between Shumard and himself. Both the statements made and the manner in which they are presented are such as to prejudice the unbiased reader against Mr. Buckley, and this in particular when one reflects that there was no apparent occasion for the publication in an official report of matters of this nature. Buckley was replied to vigorously by A. R. Roessler, who had also been one of Shumard's assistants.

The main portion of both reports was given up to a discussion of economic problems, and little that was new geologically appeared. He noted the eruptive nature of Pilot Knob, but was unable to determine whether the period of eruption antedated the Cretaceous or not. Much space was devoted to a discussion of soils and crops, together with notes on the fauna and flora.

In his report on the geology of Massachusetts (1833), and again in 1835 and 1841, Dr. Edward Hitchcock called attention to the flattening and distortion of pebbles in a conglomerate near Newport, Rhode Island, as already noted. As time went on the importance of the subject, particularly in the light of subsequent discoveries, seems to have grown upon him, and in a paper in the American Journal of Science for 1861, and in his reports on the geology of Vermont for that same year, the ground is gone over in great detail and his gradually expanding views fully elaborated.

Hitchcock's Views on the Metamorphism of Conglomerates, 1861.

In his report of 1833 the conglomerates were described as composed of elongated rounded nodules of quartz rock passing into mica slate, with a cement of talcose slate, all with their longest diameters uniformly parallel, the entire mass, pebbles and all, being divided by fissures as perfect as if "cut through by the sword of some Titan." Later, while engaged in the work of the Vermont survey, he found analogous conglomerates along nearly the whole western side of the Green Mountains, and in 1859, in company with his son, C. H. Hitchcock, he again visited the Newport locality in search of facts to aid him in solving the Vermont problem. His results were given before the American Association for the Advancement of Science that same year, and the subject again brought before the Association by C. H. Hitchcock in 1860.

The facts brought out and presented showed the pebbles to be (1) much elongated in the direction of the strike of the beds; (2) that, while flattened, this feature was not so striking as their elongation; (3) that they were often indented by one being pressed into another; (4) that they were often bent, sometimes in two directions; and (5) that they were cut across by parallel joints, or fissures, at intervals of from a few inches to many feet. These facts led him to conclude that (1) the rock had once been a conglomerate of the usual character, and had undergone a metamorphosis whereby the cementing material had become crystalline and schistose and the pebbles elongated, and

(2) the pebbles themselves had been in a more or less plastic state; otherwise any attempt at change in form would result only in fracture and comminution. The clean manner in which the pebbles were cut by joints was thought also to indicate a condition of plasticity. The flattening and distorting force was thought to have operated laterally, and the jointing regarded as due to some polarizing force acting upon soft materials, a simple inspection of the rock in place being sufficient to satisfy anyone that no mechanical agency would alone be sufficient to produce the phenomena. Applying the same method of reasoning to the conglomerates of Vermont, he came to the conclusion that these, too, had undergone metamorphism, giving rise to schists and gneiss, and that, indeed, granites and syenites might result from the metamorphism of stratified rocks. The chemical details as worked out would naturally not hold in their entirety to-day, and of course the idea of a polarizing force would be no longer seriously considered; but the fact remains that this paper, as a whole, marks a long stride in advance along the line of metamorphism, and for its time was comparable in its importance with the later work of Lehmann on the crystalline schists of Saxony.[a]

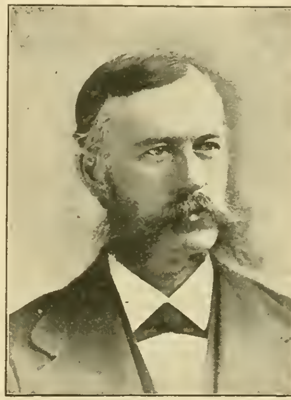

FIG. 73.—Charles Henry Hitchcock.

Natural History Survey of Maine, 1861–62.

By an act of the legislature approved March 16, 1861, Ezekiel Holmes, of Winthrop, Maine, was commissioned, under the direction of the board of agriculture, to make a scientific survey of the State. C. H. Hitchcock, then of Amherst, Massachusetts, and a son of Dr. Edward Hitchcock, was commissioned geologist, while George L. Goodale served as botanist and chemist, C. Houghton as mineralogist, A. S. Packard, jr., as entomologist, and C. B. Fuller as marine zoologist. Others, including G. L. Vose and Dr. N. T. True, rendered assistance at various times.

Two brief seasons were devoted to field work, the results of which appeared in the reports of the board of agriculture for 1861–62, the strictly geological portions being limited to some six hundred and odd pages. The work done under these conditions was necessarily somewhat disconnected. Northern Maine was still practically a wilderness;

[a] The subject was in 1868 again taken up by Prof. G. L. Vose, whose conclusions, based on a study of conglomerates in the vicinity of the Rangeley Lakes, were largely confirmatory of those of the Hitchcocks. He was not, however, disposed to regard the pebbles as having been in a plastic state, but contended that under the forces that had there prevailed rigid pebbles might be bent and flattened in the manner described.

there were no maps and absolutely no railroads. A geological map in black and white was, however, prepared of the region north of Calais and the 45th parallel, and also one of the eastern portion of the State included between St. George and Belfast.

The fossiliferous rocks were noted as mostly Paleozoic and probably all lying below the Carboniferous series. The red sandstone of Perry, the problematic horizon of which had been discussed by Jackson and others, as previously noted in these pages, was regarded as "indisputably Devonian," this statement being based upon expressed opinions of Jackson, Rogers, Newberry, and Dawson. It was noted that the fossiliferous marine clays, which were regarded as of the same age as the similar deposits along the St. Lawrence and the Champlain valleys and referable to the Terrace period, sometimes underlay a coarse deposit referable to the unmodified drift. Without committing himself definitely on this point, Hitchcock suggested the possibility, therefore, of a recurrence of the drift agencies—that is, a period of second drift. This, so far as the present writer has information, is the first suggestion by an American of such a possibility. It seems, however, to have been quite lost sight of. (See also remarks of Edward Hitchcock, p. 462.)

The drift period itself, according to Hitchcock's view, was inaugurated by depression of this portion of the continent amounting to at least 5,000 feet below that of to-day. Subsequently the continent rose again gradually to its present altitude. It was during this period of depression and elevation that the drift deposits were formed through the conjoined agency of icebergs and glaciers. The various forms of modified drift he thought to have been produced largely by the aid of rivers and moving currents of water. These views were those very generally held at that date, though, naturally, they have been somewhat modified since.

The quartz rock in the vicinity of Rockland, Thomaston, and Camden was regarded as belonging to the Taconic period of Emmons, and the associated limestones were looked upon as contemporaneous with the Stockbridge limestones of Emmons or, what is the same thing, the Æolian limestones of the elder Hitchcock.

Newberry's Views on Glaciation, 1862.

Dr. J. S. Newberry, in Notes on the Surface Geology of the Basin of the Great Lakes, after a review of the surface conditions as he saw them, came to the conclusion that at a period corresponding in climate, if not in time, with the Glacial epoch of the Old World, the lake region in common with all the northern portion of the American Continent was raised several thousand feet above the level of the sea. This was the "glacial period," during which the surface of the country was planed down and the deep fiords along the Atlantic coast formed. This was followed by a period of depression, when all the basin of the Great

Lakes was flooded with fresh water, forming a vast inland sea, in which the laminated blue clays, the "oldest of our drift deposits," were precipitated. Subsequent to this deposit of blue clays "an immense quantity of gravel and bowlders was transported from the region north of the Great Lakes and scattered over a wide area south of them." This was due to floating ice and icebergs. The lake ridges (ancient beaches), described by Whittlesey, Newberry regarded as evidence that the water of the lakes remained for considerable intervals much higher than at present. These are practically the same views announced before the New York Lyceum in 1870 (p. 545).

In May, 1862, J. P. Lesley read a paper before the American Philosophical Society describing the structure of the Allegheny Mountains, in which he assumed that the rocks of the Blue Ridge Range, on the eastern side of the valley, were a prolongation of the Green Mountains of Vermont, and consisted, therefore, of the Quebec group, or Taconic System. In this he followed the Rogers Brothers, as he acknowledged. He accounted for the change in the drainage, as exhibited by the New River, which breaks into the Appalachians, as due to a structural change in the geology, most of the mountain valleys north of this being unbroken anticlines and synclines, while most of those south of it are monoclines bounded by immense faults or downthrows. The Appalachians of southern Virginia and eastern Tennessee are grouped in pairs by faults, the fracturing being in parallel strips from 5 to 6 miles wide, each strip being tilted easterly so that the upper edge of one strip, with its Carboniferous rocks, abuts against the bottom or Lower Silurian edge of the strip next to it. The Paleozoic zone, therefore, included between the Great Valley and the backbone escarpment, is occupied by as many pairs of parallel mountains as there are parallel faults, and as these faults lie in straight lines at nearly equal distances from one another the mountain ranges run with great uniformity side by side for 100 or 200 miles until cut off by cross faults, or by change in the courses of the principal faults.

Lesley on Mountain Structure, 1862.

In a paper before the American Philosophical Society the year following on a "remarkable coal mine or asphalt vein in the Coal Measures of Wood County, (West) Virginia," Lesley was led into a discussion of uplift and erosion, and expressed sundry ideas worthy of note.

J. P. Lesley on uplift and erosion, 1863.

Assuming that the valley cutting through this mine was one of erosion and had been carved out since the vein was filled, Lesley speculated on the time and causes of erosion and incidentally on the character of the original uplift. He rejected the idea of cataclysmic erosion dating back to the time of the uplift, as he did also that of the secularists, who regard the present face of the country as but the latest phase of an infinite series of oceanic degradations, beginning with the uplift and still in progress. Instead, he adopted the supposition of a succession of denuding actions of unknown force and indefinite number. "A homogeneous element with sufficient force, acting either by one or by repeated blows," would bring about the present condition of affairs.

No one will deny that water, if obtained in sufficient quantity at a sufficient velocity, would be such an agent. In the acknowledged instability of the crust of the earth, in its acknowledged less stability in ancient times than now, we find the possibility, nay, we feel the certainty, that the oceans have at times been launched across the continents, and we need nothing more to satisfy all the conditions for an explanation of Appalachian topography.

One great obstacle, Lesley thought, in the way of topographical science among geologists—

has been an innocent ignorance of the titanic postulates upon the ground, and therefore an inability to reconstruct in imagination the awful vaults of rock which have been removed from over at least 50,000 square miles of the surface of the United States merely along the one belt of the Appalachian Mountains, between the coal area and the Blue Ridge range.

However this may have been, Lesley himself could not be accused of any such innocent ignorance and consequent impotency of imagination. Thus, when speculating on the character of the folds of the Appalachians, as controlled by the roughness of the old surface of the more or less disturbed and eroded sedimentaries and the thinness of the newer formations, whereby there was a tendency for more or less hitch and catch below and crack and shove above, he showed that such features were here reduced to a minimum, and hence probably the high anticlines were unbroken at the crest.

As a whole, the plicating energy must have acted with a steady evenness of thrust, which carried up the anticlinal waves of the crust unbroken, and in some cases to a height of between 5 and 10 miles above the present surface level.

Truly a strange admixture of views. As a modern catastrophist he was equaled only by Clarence King.

It was the opinion of Rogers, it will be remembered, that the great amount of erosion which had manifestly taken place in the Pennsylvania Appalachians was cataclysmic, the consequence of a great rush of waters or body of water over the face of the continent at the time when the coal era was about to be terminated by the upheaval of the whole Appalachian belt of earth crust, when it was thrown into waves or folds. Lesley at first accepted this view and even as late as 1864 confessed himself as not entirely convinced that such a cataclysm was not necessary in order "to explain the earlier and perhaps the larger part of the whole phenomenon." He did not, however, accept Rogers's "pulsating planetary lava-nucleus" theory to account for the primary origin of the range, but felt that the force of lateral thrust caused by shrinkage from a cooling globe better accounted for the surface convolutions as he saw them.

Chester Averill, William More Gabb, William Ashburner, James Dwight Whitney, Charles F. Hoffman, Clarence King, William Henry Brewer.

MEMBERS OF THE GEOLOGICAL SURVEY OF CALIFORNIA, 1860.

In 1860 J. D. Whitney was appointed State geologist of California and served until 1874, when the survey was discontinued. According to the original act, he was required to make an accurate and complete geological survey of the State and to furnish a report containing a full scientific description of its rocks, fossils, soils, and minerals, and of its botanical and zoological productions. W. H. Brewer was principal assistant in botany and agricultural geology, William Ashburner in mining, and W. M. Gabb, paleontologist. Clarence King also rendered assistance in a volunteer capacity.

Whitney's Geological Survey of California, 1860-1869.

The results of this survey are embodied in three volumes on geology and paleontology published by the State and two volumes on the auriferous gravels, published by the Museum of Comparative Zoology at Harvard after Whitney's retirement. It was announced in the statement of progress for 1872-73 that a geological map of the whole State had been colored, but it seems never to have been published.

The first volume of Whitney's report of progress and a synopsis of field work from 1860 to 1864 appeared in 1865. This comprised a small quarto volume of 498 pages. The volume contained a great amount of descriptive matter relating to the areal geology of various parts of the State, particularly of the Coast Ranges and Sierra Nevada, with a chapter on the mining regions.

Whitney decided, from the discovery of a single shell in the rocks of Alcatraz Island, that the so-called San Francisco sandstone was of undoubted Cretaceous age. The serpentines of Mount Diablo and the San Francisco peninsula he considered as metamorphic sediments (sandstone)—a mistake which was later repeated by Becker in his volume on the quicksilver deposits of the Pacific slope.

Whitney was decidedly pessimistic regarding the probability of the occurrence of petroleum on the Pacific coast, and unhesitatingly discouraged the promoting of enterprises of this nature. With reference to the region south of the Bay of Monterey, he wrote:

> As the bituminous shales are everywhere turned up on edge and have no cover of impervious rock, the inference is unavoidable that flowing wells, or at least those delivering any considerable quantity of liquid petroleum, can not be expected to be got by boring to any depth. The probabilities, at least, are against it.

When one reflects that the output of the California fields in 1899 amounted to 2,677,875 barrels, he is led to question the infallibility of Whitney's judgment in these matters.

Whitney considered all those chains or ranges of mountains in California to belong to the Coast Ranges which had been uplifted since the deposition of the Cretaceous formation; those which were elevated before the Cretaceous as belonging to the Sierra Nevada. The slates of the western slope in Mariposa County were regarded as of Jurassic age, and the Calcareous slates of Plumas County as belonging to the

Triassic. The limestones in the Gray Mountains had been referred by Doctor Trask to the Carboniferous formation. With this reference Whitney agreed.

The peculiar dome-shaped concentric structure of the granite in the Sierras was dwelt upon with considerable detail, and the curved structure of the sheets regarded as having been produced by the contraction of the material while cooling or solidifying. The Yosemite Valley itself he thought to be due to a differential movement, the half dome seeming beyond a doubt to have been split asunder in the middle, one-half having gone down in what he calls "the wreck of matter and the crush of worlds." In other words, he regarded the valley as due to the downward drop of an enormous fault block.[a]

The first volume of the paleontological reports appeared in 1864. This comprised 243 pages, with 32 full-page plates of fossils, the Carboniferous and Jurassic being described by F. B. Meek, and the Cretaceous and Triassic by W. M. Gabb. Concerning the work thus far done, Whitney wrote:[b]

> Perhaps the most striking result of the survey is the proof we have obtained of the immense development of rocks, equivalent in age to the upper Trias of the Alps, and paleontologically closely allied to the limestones of Hallstadt and Aussee, and the St. Cassian beds, that extremely important and highly fossilliferous division of the Alpine Trias.

Further on he says:

> Enough (fossils), however, have been found to justify the assertion that the sedimentary portion of the great metalliferous belt of the Pacific coast of North America is chiefly made up of rocks of Jurassic and Triassic age. * * * While we are fully justified in saying that *a large portion of the auriferous rocks of California consist of metamorphic Triassic and Jurassic strata*, we have not a particle of evidence to uphold the theory * * * that all or even a portion are older than the Carboniferous. * * * We are able to state * * * that this metal (gold) occurs in no inconsiderable quantity in metamorphic rocks belonging as high up in series as the Cretaceous. (P. 261.)

Subsequent to this, apparently[c] W. P. Blake, as geologist of the California State Board of Agriculture, made a claim to having, in 1863, found on the American River a fossil ammonite, which he regarded as establishing the secondary age of the gold-bearing strata. It was claimed by Prof. W. H. Brewer, however, that Blake did not know for a certainty if the specimen was found in place or, indeed, if it were an ammonite or ceratite; also that the fossils were not found so early as the date claimed by Blake (1863). Brewer is very emphatic in his statements to the effect that Whitney was the first to announce

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[a] Later investigators have been inclined to regard the valley as due merely to river erosion, facilitated by the vertical jointing of the rocks. (See H. W. Turner, Proc. California Academy of Sciences, Geology, I, No. 9, 1900.)

[b] American Journal of Science, XXXVIII, November, 1864, pp. 256–264.

[c] See American Journal of Science, XLII, 1886, p. 114.

JAMES RICHARDSON. ALEXANDER MURRAY. SIR WILLIAM LOGAN.

the Jura-Trias age of these rocks, and the extracts from the published reports seem to bear him out.

The second volume of the paleontological reports, as published in 1869, comprised 299 pages, with 36 full-page plates, and was given up wholly to descriptions of Tertiary and Cretaceous fossils by Gabb. In his introductory note Whitney reiterated his statement above quoted regarding the age of the gold-bearing rocks and the absence of rocks older than Carboniferous, not merely in the State, but west of the one hundred and sixteenth meridian.

As previously noted (p. 385), Logan, during his period of service as provincial geologist, submitted sixteen reports dealing mainly with stratigraphic and economic subjects. In 1863 he brought forward a long promised volume—The Geology of Canada—a large octavo, of 983 pages, accompanied by an atlas giving a colored geological map and sections.

Logan's Geology of Canada, 1863.

Logan was assisted during the early part of his work by Alexander Murray and James Richardson, geologists; E. Billings, paleontologist, and T. Sterry Hunt, chemist. Later Robert Bell, now (1904) acting director, and others of less prominence, were added to the force. A portion of the paleontology was assigned to James Hall, and the nomenclature adopted was essentially that of the New York survey.

The map accompanying the volume was beautifully executed in colors, and comprised all of the provinces southeast of the St. Lawrence as well as a narrow belt composed mainly of Laurentian, extending from Labrador southwesterly to the Great Lakes, and thence northwesterly to the ninety-sixth meridian. It included a considerable portion of the United States, data for which were supplied by Hall and other American geologists.

Overlying the graptolitic shales of the Utica and Hudson River formations in the vicinity of Quebec, Logan found a conformable series of sandstones, shales, and conglomerate limestones, which he considered, in spite of their position, as older than the Hudson River group formation and to which he applied, from their geographical position, the name of the Quebec group. This was again subdivided into an underlying green sandstone series called the Sillery formation, and an overlying Levis formation. These were supposed by both Logan and Billings to be mainly contemporaneous with the Calciferous and Chazy groups of the New York geologists, but more recent investigations by Selwyn and Ellis have shown that while the Levis beds are Calciferous in the lower parts, the Sillery is probably all Cambrian (Dana), the Quebec, as a whole, being a northern continuation of the Taconic series. By a singular error, to which Marcou was prompt to call attention, this Quebec group on the map referred to above was made to include the Chazy and Calciferous formations below the Trenton.

It is worthy of note that, while Logan's successors have been invariably opposed to the idea of the origin of the drift and rock striations through a glacial ice sheet, Logan evidently committed himself to this theory. Concerning the origin of the lake basins of western Canada he writes:

These great lake basins are depressions, not of geological structure, but of denudation, and the grooves on the surface rocks, which descend under their waters, appear to point to glacial action as one of the great causes which have produced these depressions.

Again, in a footnote on the same page, he quoted, with evident approval, the following:

This hypothesis (i. e., the origin of the lake basins) points to a glacial period when the whole region was elevated far above its present level, and when the Laurentides, the Adirondacks, and the Green Mountains were lofty Alpine ranges, covered with perpetual snow from which great frozen rivers or glaciers extended over the plains below, producing by their movements the glacial drift and scooping out the river valleys and the basins of the lakes.

It was in this same report that Logan first noted the occurrence of a supposed fossil in the Laurentian of Canada, describing under the name of *Stromatopora rugosa* an aggregate of crystalline pyroxene and calcite found by Mr. John Mullen in one of the bands of limestone at the Grand Calumet. This was the so-called Eozoon of Dawson, referred to elsewhere.

Logan, for his time, possessed a very profound insight into petrographical problems, though he naturally regarded as traces of an original bedding what is now known to be, in part, at least, foliation due to dynamic causes. Thus, in his reports for 1853–1856, he wrote concerning the rocks of the Laurentian system:

They are the most ancient yet known on the continent of America, and are supposed to be equivalent to the iron-bearing series of Scandinavia. Stretching on the north side of the St. Lawrence from Labrador to Lake Superior, they occupy by far the larger share of Canada, and they have been described in former reports as sedimentary deposits in an altered condition, consisting of gneiss interstratified with important bands of crystalline limestone (p. 7).

And again:

The Laurentian series are altered sedimentary rocks.

The geology of the islands of Anticosti, Mingan, and the Magdalen River region was assigned by Logan to James Richardson, who made his report in 1857. The fossils collected were worked up by Billings, who considered the rocks of the Anticosti group to consist of beds of passage from the Lower to the Upper Silurian and synchronous with the Oneida conglomerate, the Medina sandstone, and the Clinton group of the New York survey, and with the Caradoc formation of England.[a]

The possibility that the Laurentian system might not be a single unit was here again recognized by Logan in a supplementary note:

If, on exploration to the eastward of the Trembling Mountain, it should be further ascertained that the two inferior limestone bands of the Greenville series disappear on reaching the margin of the anorthosite, it may be considered as conclusive evidence of the existence in the Laurentian system of two immense sedimentary formations, the one superimposed unconformably on the other, with probably a great difference in time between them; and it will be an interesting subject of inquiry whether the intrusive rocks which have been found intersecting the lower division give any clue to events which may have happened in the interval.

Logan was born of Scottish parentage at Montreal in 1798, but his father shortly returning to Scotland, he received his early training, which was classical, in the High School and University of Edinburgh.

Sketch of Logan.

He showed no disposition toward scientific pursuits until chance led him to the keeping of accounts in the establishment of an uncle, who was interested in mining and copper smelting operations in Wales. Here he was attracted by the phenomena of the coal seams and devoted a large share of his spare time to their study.

In 1838 the death of his uncle caused him to give up his position in Wales, and in 1840 he returned to Canada. His first geological paper was on the character of the beds of clay immediately below the coal seams of South Wales. This was communicated to the Geological Society of London in 1840. In this he announced the invariable presence under the coal seams of beds of fire clay carrying Stigmaria. This he regarded as proving the origin of coal through plant growth in place—an opinion which was very generally accepted at that time.

When Logan began his geological work in Canada a large portion of the country was a wilderness, without roads, and there were no maps. Of the topography of the Gaspé district it is written:

Little was known of the region beside the coast line; of the geology, practically nothing. Settlements were few, confined almost exclusively to the coast, and made up chiefly of fishermen. There were no roads through the interior, most of which was, and indeed still is, a wilderness, inhabited by bears and other wild beasts, or at best only penetrated in certain regions by a few Indians or lumbermen. The courses of most of the streams were unknown and the mountains untraversed.

Living the life of a savage, sleeping on the beach in a blanket sack, with my feet to the fire, seldom taking my clothes off, eating salt pork and ship's biscuit, occasionally tormented by mosquitoes.

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[a] Prof. N. S. Shaler, in a paper before the Boston Society of Natural History, December 18, 1861, antagonized that view and argued that from the base of the level of the Canadian channel to the summit at the southwestern point of the island the beds were entirely Upper Silurian and synchronous with the Clinton and Niagara, of New York and elsewhere, though the fossils themselves might not be absolutely identified.

Such is the record Logan has left us of his Gaspé experience. From early dawn to dusk he paced or paddled, and yet his work was not finished, for while his Indians—often his sole companions—smoked their pipes around the evening fire he wrote his notes and platted the day's measurements.

Logan is represented to us as strong in body, of active mind, industrious, and doggedly persevering, painstaking, a lover of truth, generous, possessed of the keenest knowledge of human nature, sound of judgment, but always cautious in expressing an opinion.

During his twenty-seven years of office, sixteen reports were submitted, the first, that for the year 1843, appearing in the form of a pamphlet of 159 octavo pages. It contained remarks on the mode of making a geological survey and a short preliminary report containing general observations on the geology of the provinces, and adjacent portions of the United States, together with the Joggins section already mentioned.

Fig. 71.—Thomas Sterry Hunt.

Assisted by Mr. Alexander Murray, and later by the chemist, T. Sterry Hunt, Logan continued his work until 1869, when he resigned to be succeeded by Mr. Selwyn. His reports cover the geology of Ottawa, the Gaspé peninsula, the economic geology of the Lake Superior region, the geology of lower Canada with especial reference to the eastern townships, the region along the north coast of Lake Huron, the gold-bearing fields of the Chaudière region, and the western peninsula, also the region between the Ottawa, the St. Lawrence, and the Rideau. His most important publication was his geology of Canada, noticed above. His geological map, bearing date of 1866 and measuring 8 by 3½ feet, is said to have been the largest and most comprehensive that had appeared up to that time.

Under the directorship of Logan, Alexander Murray, assisted by James P. Howley, began work on the geology of Newfoundland in 1864, making a first brief report in May, 1866. The survey was continued until 1880, and a reprint of all the reports published in book form—an octavo volume of 536 pages—in 1881.

Work of Murray and Howley in Newfoundland, 1864.

The work as a whole consisted mainly of details of structure of the regions immediately along the coast, with notes on the mines. The various subdivisions of the formations adopted were naturally those of the Canadian survey, which were based to a considerable extent upon those of the New York survey.

Naturally, Murray's observations were limited mainly to a comparatively narrow belt along the coast. With the exception of the Glacial and post-Glacial material, no formations were found of later date than the Carboniferous. The succession of the Lower Silurian formations of the island from above downward he gave as follows: Sillery, Lauzon, Levis, Upper Calciferous, Lower Calciferous, Upper Potsdam, Lower Potsdam, and St. John's Group. The St. John's Group is now recognized as Middle Cambrian (?), while his Lower Potsdam is Lower Cambrian.

Before the beginning of Murray's work it had already been shown by Richardson, working under direction of Logan, that a trough of Lower Silurian rocks must underlie the northern part of the Gulf of St. Lawrence, gradually narrowing toward the Strait of Belle Isle, one side of the trough rising on the coast of Labrador, while the other formed the western shore of Newfoundland from Bonne Bay to Cape Norman. On each side of the Strait these rocks were found to rest on Laurentian gneiss, which was ascertained to extend from the neighborhood of Bonne Bay to within 12 or 15 miles of Hare Bay.

Murray's investigations proved that the Laurentian rocks spread in breadth to the Atlantic coast of the great northern peninsula of the island, and that the base of the Lower Silurian strata, sweeping around the northern extremity of the gneiss, comes upon the coast near Canada Bay, and again strikes into the land at Coney Arm in White Bay, where the Lower Silurian are overlaid by Upper Silurian, followed by rocks of Devonian age. Farther to the southeast the Laurentian and Silurian series were found to be partially and unconformably covered by rocks of Carboniferous age.

The report was accompanied by a colored geological map on ten sheets, on a scale of 25 miles to the inch.

As already noted, the Canadian geologists, with the exception of Logan, have never taken kindly to the idea of a glacial ice sheet, but have sought to account for the distribution of the drift, erosion, and allied or associated phenomena through other means.

Dawson's Views on Glaciation, 1864.

Thus, J. W. Dawson, in his address before the Natural History Society of Montreal in 1864, took occasion to combat vigorously the idea, on the ground that "it requires a series of suppositions unlikely in themselves and not warranted by facts;" that it seems physically impossible for a sheet of ice to move over an even surface, striating it in uniform directions over vast areas; that glaciers could never have transported the large bowlders and left them in the positions found, having no source of supply; that the peat deposits, fossils, etc., show that the sea at that period had much the same temperature as the present Arctic currents, and that the land was not covered by ice.

Dawson's Address Before the Natural History Society of Montreal, 1864.

In describing the northeasterly and southwesterly and northwesterly and southeasterly directions of the rock striæ, he announced that he had no hesitation in asserting that the force which produced the southwesterly striæ was "from the ocean toward the interior, against the slope of the St. Lawrence valley," and as he could not conceive of a glacier moving from the Atlantic up into the interior he considered this as at once disposing of the glacial theory. He conceived, rather, that a subsidence took place sufficient to convert all the plains of Canada, New York, and New England into sea. This, he felt, would determine the direction of the Arctic current which would move up this slope. He would account for the excavation of the basins of the Great Lakes in a similar way. Supposing the land submerged so that the Arctic current from the northeast should pour over the Laurentian rocks on the northern side of Lake Superior and Lake Huron, it would cut out the softer strata, forming the basins and drifting the material to the southwest.

The lower strata of this current would be directed through and between the Laurentide hills and the Adirondacks, and, flowing over the ridge of hard rock which connects them at the Thousand Isles, would cut out the basin of Lake Ontario and heap up at the same time the mass of bowlder clay intervening between Lake Ontario and Georgian Bay. Lake Erie, he thought, might have been cut by the flow of the upper layers of water over the middle Silurian escarpment, Lake Michigan being likewise due to this unequal erosion. The northwesterly and southeasterly striæ he conceived were produced by a return of the northeast-southwest current, obstructions causing it to flow along the valleys of Lake Champlain, the Connecticut, and the low country between Lake Ontario and Lake Huron. He would not wholly exclude the action of glaciers, but thought such were limited to the mountain tops. Old sea beaches, he thought, had been mistaken for moraines, and he found evidences of ocean breakers almost to the summits of the White Mountains. Lake basins and fiords in the northern latitudes are all due to current and wave action, the cold Arctic currents being appealed to rather than the warm surface currents. He also felt sure that the numerous indentations of the coast of the United States were due to the action of waves rather than of ice.

Pumpelly's Work in China, 1863-64.

In the autumn and winter of 1863–64 Raphael Pumpelly, of Rhode Island, was engaged by the Chinese Government to examine the coal fields west of Peking. Incidentally he made journeys in northern China and Mongolia. Subsequently, in 1864–65, he crossed into Siberia and journeyed overland to St. Petersburg. The results of his observations on the geology of the region were published in the Smithsonian Contributions to Knowledge, 1866, forming a quarto pamphlet of 144 pages with 8 plates of sections, and a colored geological map, the latter confessedly hypothetical. This memoir, which antedated Richthofen's great work on China by some years, gave to the world the first authentic account of the geology of the region.

He showed that in the region extending from the twentieth to a little beyond the fortieth parallel and from near the one hundredth to about the one hundred and twenty-second meridian the oldest sedimentary rocks were Devonian limestones, which prevailed in some cases to the enormous thickness of 11,600 feet. Overlying this, through the greater part of the area, were the Chinese Coal Measures (Mesozoic), interrupted by bands of granitic and metamorphic rock of undetermined age. In the extreme northern part of this region was a comparatively small area of basaltic and trachytic rocks. The region immediately south of Peking, comprised principally within the provinces of Chihli, Nganhwui, Kiangsu, and Shantung, was colored, as occupied by post-Tertiary materials, with smaller areas of the same age along the Yangtse-Kiang and Hoangho rivers in the provinces of Hupeh, Sz'chuen, and Shensi.

Fig. 75.—Raphael Pumpelly.

Considerable attention was given to the post-Tertiary "Terrace" deposit, or loam, which he found in the valley of every tributary of the Yang Ho, and probably also of the Sankang Ho. This, which has since become more generally known as the Chinese loess, was described in considerable detail as to modes of occurrence, physical properties, and geological distribution. The material he regarded as having been deposited in a chain of lakes extending from Yenkingchau north-northwest of Peking to near Ninghia, in Kansuh, a distance of nearly 500 miles, the lake basins themselves being formed by the dislocations which gave rise to the plateau wall to the north, and being filled by sediments brought by the Yellow River.

The fossil plants brought by Pumpelly from the coal-bearing rocks were studied by Newberry and identified as of Mesozoic age.

George H. Cook, who was assistant geologist of New Jersey under the Kitchell survey (suspended in 1856), was appointed State geologist with the reorganization of the same survey in 1863, and continued to serve in this capacity until the time of his death in 1889. His first annual report, that for 1864, bearing the date of 1865, was a small pamphlet of but 20 pages, and contained a single-page colored geological map of the State, the second of its kind to be issued, the first having been by H. D. Rogers.

Cook's Survey of New Jersey, 1863–1889.

One of the first tasks which Doctor Cook imposed upon himself after his appointment was the preparation of a large octavo volume, accompanied by a portfolio of maps, setting forth the condition of the knowledge of geology of the State up to the date of publication (1868). In this work he gave a general summary of all his previous work, and upon it we will draw largely for other facts which may be given here.

Naturally the question of the age and stratigraphic position of the white limestone came up for discussion. He quoted the opinion of Rogers (p. 326), and found reason for differing with him. He wrote:

> In regard to the crystalline limestones he was mistaken. They are everywhere conformable to the gneiss and interstratified with it. His mistake is acknowledged by his former assistant, J. P. Lesley, in the American Journal of Science, LXXXIX, p. 221. The true position and identity in age of the crystalline limestone and gneiss was proved by Vanuxem and Keating, in the Journal of the Academy of Natural Sciences in 1822, and this view has been sustained by all the observations of Doctor Kitchell and his assistants and can be easily verified by anyone who will visit the localities cited in this report.[a]

Cook was inclined to regard the magnetic iron ore as of sedimentary origin, deposited in beds just as were the gneiss and crystalline limestone, in this respect agreeing with Doctor Kitchell and disagreeing with H. D. Rogers.

As early as 1854 Cook had called attention to the gradual subsidence of the coast of New Jersey, and before his death was able to give absolute figures regarding the rate of depression.

Cook was born in Hanover, New Jersey, in 1818, and educated in the public schools of the State and the Rensselaer Polytechnic Institute, whence he graduated in 1839 with the degree of C. E. After graduation he remained at the Institute as tutor, adjunct professor, and finally full professor, until 1846, when he removed to Albany, New York, where he was engaged at first in business and latterly as professor of mathematics and natural philosophy, and finally principal of the Albany Academy.

Sketch of Cook.

In 1852 he was sent to Europe by the State authorities of New York to study the salt deposits, with a view of developing those of Onondaga County. In 1853 he accepted a call to the chair of chemistry and natural sciences in Rutgers College, New Jersey, retaining his connection with the institution during the remainder of his life, though after 1854 being actively connected with the State geological survey. In 1880, moreover, he was made director of the State agricultural experiment station, which, indeed, had been established largely through his efforts.

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[a] Studies by Mr. A. C. Spencer, of the United States Geological Survey, made during the season of 1904, point to an igneous origin for the gneiss. This view, of course, effectively disposes of the idea that the limestone is conformable with the gneiss and interstratified with it.

GEORGE HAMMELL COOK.
State Geologist of New Jersey.

A noble and unselfish man, who, as some one has expressed it, "went in and out of the houses of this State, making friends of every man, woman, and child he met." Farseeing, persistent, ever calm and judicious in his work, yet light hearted and cheerful among his friends—

his broad expanse of face, full of light, his eyes gleaming with kindliness, as well as with shrewdness, and often with a right-merry twinkle; his genial smile, his frank greeting, never marred by any hollow and flippant phrase of mere etiquette, but as honest as it is cordial; his sympathy, so responsive yet so genuine; his massive though quiet strength of purpose; and his self-contained, self-poised nature, all crowned with boundless hopefulness, united to make his very presence an inspiration and benediction.

In the author's memory there are two men among American geologists who stand out as devotees of science, yet entirely free from the narrowness of the specialist or the personal idiosyncrasies that so frequently mar the character of men of their class. These two men are George H. Cook and Edward Orton. They loved science for science sake, yet did not close their eyes to its economic bearing, nor call upon an overtaxed public to support them in the work they loved, regardless of its outcome. Never a minister of the gospel had the interests of his parishioners more at heart than these two men that of the public they served. For themselves they asked simply the privilege of doing the work and doing it to the best of their ability.

FIG. 76.—Benjamin Franklin Mudge.

Work of B. F. Mudge in Kansas, in 1864.

B. F. Mudge, as State geologist, submitted his First Annual Report on the Geology of Kansas for the year 1864, in form of an octavo volume of 56 pages, in 1866. He announced the lowest geological formation of the State to be the upper portion of the Coal Measures, of which he gave a section in Leavenworth County. He accepted the identification of the Permian age of the fossils which had been described by Meek, Hayden, and Swallow, and noted the occurrence of the Triassic and probably the Jurassic also, in a belt of territory crossing the Republican and Smoky Hill valleys, and also the Cretaceous, the geographic limits of which had not been worked out. He regarded the drift and erratic bowlders as due to icebergs.

Sketch of Mudge.

Professor Mudge was born in Maine in 1817, and graduated at Wesleyan University, Connecticut, in 1840. After graduation he studied law and, being admitted to the bar, practiced his profession in Lynn, Massachusetts, until 1859. During 1859 and 1860 he was employed as chemist in the Chelsea, Massachusetts, and Breckinridge, Kentucky, oil refineries, and in 1861 he removed to what is now Kansas City, Kansas, where he engaged in teaching. Such a life would now be considered as little fitting a man for the profession of geology, yet in 1864, having by invitation delivered a course of lectures before the Kansas legislature upon the geological resources of the State, he was unanimously elected State geologist, a position which he, however, filled for but a single year, resigning to accept the professorship in natural history in the Agricultural College at Manhattan, where he remained until 1873. His resignation from this last position is stated to have been caused by disgust aroused at the political conditions in which the institution became involved and the assumption of its presidency by a well-known politician, with no qualifications whatever for the position.

Although by profession a lawyer, Mudge is stated to have been throughout his whole life deeply interested in natural sciences, and while in Lynn to have taken an active part in the organization of the Lynn Natural History Society. In Kansas his scientific work was largely in the line of exploration.

Arduous, intrepid, willingly undergoing hardships and dangers for the sake of science, he explored a very large part of Kansas when explorations meant real dangers and hardships of the most pronounced kind. As early as 1870 he made explorations in the extreme western part of the State in the study of its geology and paleontology, and for years afterwards nearly every summer found him in the midst of the Indian country, usually wholly without protection from the danger of hostile Indians, save such as his own rifle and revolver afforded. In the summer of 1874 he explored the whole length of the Smoky Hill River, an utterly trackless wild, infested by Indians, whose murderous depredations were visible on every side.

Mudge's bibliography is brief and the papers generally limited to but a few pages at most. His material he willingly put in the hands of others for publication, and Marsh, Cope, White, and Lesquereux profited thereby. It was during one of these earlier trips that he discovered the first specimen of Ichthyornis, which, coming into the hands of Marsh, did so much toward making the latter famous.

Mudge made the first geological map of the State (Kansas), which is fairly correct in its main features, save for the Lower Cretaceous, which he failed to recognize.

He mapped and described with tolerable accuracy and fullness the physical structures of the different Cretaceous and Tertiary horizons. Much, if not most, of the information thus given was based upon his patient researches in wagon or on foot. In general it may truthfully be said that his pioneer work in Kansas geology was important and extensive, though now largely superseded by more detailed and accurate studies. His work in life, however, has chiefly borne fruit as a teacher. He was widely known as an enthusiastic and able lecturer, and his courses were always in demand by the teachers and scientific men of the State. His quiet modesty and unselfishness disarmed all envy and jealousy. Of most charming personality, of wide culture, and unbounded enthusiasm, his teachings made an unusual impression upon all with whom he came in contact.

In 1866, G. C. Swallow, who succeeded B. F. Mudge as State geologist, issued a Preliminary Report of the Geological Survey of Kansas, in form of an octavo volume of 198 pages, including a report by Dr. Tiffin Sinks on the Climatology, and one by Dr. C. A. Logan on the Sanitary relations of the State. Maj. F. Hawn was assistant geologist.

Swallow's Geological Survey of Kansas, 1866.

Special attention was given to the eastern and central part of the State. He found rocks belonging to Quaternary, Tertiary, Cretaceous, Triassic (?), Permian, Lower Permian, and Carboniferous formations, the lowermost division being the Lower Carboniferous. The buff, mottled, and red sandstones underlying the Cretaceous were doubtfully referred to the Triassic from their resemblance to the foreign Triassic and the presence of a *Nucula* resembling the *Speciosa* of Munster from the Muschelkalk of Bindlock. The presence of Permian beds, it will be remembered, he had previously announced. The coal-bearing rocks he estimated at 2,000 feet in thickness and underlying an area of over 17,000 square miles. In these he announced twenty-two distinct and separate beds of coal, ranging in thickness from 1 to 7 feet.

Fig. 77.—George Clinton Swallow.

This work of Swallow in Kansas has been largely overlooked by recent workers. According to Keyes,[a] a large portion of it was not only good but marvelously well done for its day and the conditions under which it was accomplished. The historical importance of Swallow's work "lies in the fact that some of his geographic names applied to geologic terranes will have to stand as valid terms, although his correlations were often very bad."

Swallow, like Mudge, was born in Maine, but was of Norman-French descent. He studied the natural sciences under Parker Cleaveland, at Bowdoin College, graduating in 1843, and, after several years in educational work, accepted the chair of chemistry, geology, and mineralogy in the University of Missouri in Columbia. From 1856 to 1861, the date of the discontinuation of the survey, he served as geologist of Missouri, and in 1865 was appointed State geologist of Kansas, as elsewhere noted.

Sketch of Swallow.

He is represented to us as a large, fine-looking man, over 6 feet in height, and a very close observer of all natural phenomena. According to Professor Broadhead, "No other man during the same length of time has ever gone into a strange field, traversed the country, and published a volume all in a year and a half, as he did." Swallow was

[a] American Geologist, June, 1900, p. 347.

connected for a time (1867–1870) with mining operations in Montana, but his scientific field was limited wholly to Missouri and Kansas.

N. S. Shaler's Views on Continental Uplift, 1865.

At the December (1865) meeting of the Boston Society of Natural History, Dr. N. S. Shaler, then but twenty-four years of age and a graduate of the Lawrence Scientific School in Cambridge, made some interesting remarks on the elevation of continental masses. Referring to the assumptions of Charles Babbage and Sir John Herschel relative to the shifting of isothermal lines and consequent expansion and local uplift along lines of deposition, he went on to argue that for the same reason sea bottoms on which sedimentation was taking place would be areas of depression, since the curving must take place in the direction of greatest expansion. In like manner, uplifting would take place along lines of denudation. The intermediate point between the two zones of movement would naturally be the sea border, and hence here would occur the fracturing of the superincumbent strata and resultant volcanic phenomena. In this way, assuming the original nuclei of the continents, or points first elevated above sea level, to have been in the northern portion of the sphere, he thought it probable they would continue to grow by uplift southward in a succession of southwardly-pointed triangles.

Some six months later, in June, 1866, he read before the same society a paper on the formation of mountain chains, which is also of interest in this connection. Accepting the theory that the earth's mass consists of a solid nucleus, a hardened outer crust, and an intermediate zone of slight depth in a condition of imperfect igneous fusion, he argued, as in a previous paper, that while the continental folds were probably corrugations of the whole thickness of the crust the mountain chains were but folds of the outer portion caused by the contraction of the lower portions of this outer shell, the contraction in both cases being due to loss of heat. Further, the subsidence of the ocean's floors would, through producing fractures and dislocations along those lines, tend to promote the formation of mountain chains along and parallel with the sea borders.

Still again, in 1868, Shaler (having in the meantime been elected professor of geology in Harvard University) brought up before the Society the matter of the nature of the movements involved in the changes of level of shore lines, and this time with particular reference to changes coincident with or subsequent to the Glacial period. He showed that local phenomena of continental uplift or depression, as measured by the level of the sea at the shore line, might be variously modified by the position of the points of rotation, whether immediately at the shore line or at a greater or less distance, either seaward or inland. Of greater significance, however, were his remarks relative to the changes in level at the time of glaciation. Referring to a previous paper, where he showed that a compound bar would, when heated, bend toward the side composed of the most expansive material, he compared such a bar to a portion of the earth's crust covered with several thousand feet of ice and snow. The effect of this blanket would be to cause the isothermal lines to move outward toward the surface, causing thus an expansion of that portion of the crust immediately beneath the ice. But the ice itself would partake very slightly, if at all, of this increased temperature, and, as in the case of the compound bar, the bending would take place in the direction of maximum expansion, i. e., in this particular case, downward. In this way, he suggested, the depression accompanying the period of maximum glaciation might be accounted for.

C. F. Hartt and Orestes St. John accompanied Agassiz in the capacity of geologists on the Thayer Expedition to Brazil during the years 1865–66. In 1867 Hartt made a second journey, spending several months on the coast, between Pernambuco and Rio, exploring more particularly the vicinity of Bahia and the islands and coral reefs of the Abrolhos.

C. F. Hartt's Work in Brazil, 1865–1867.

Fig. 78.—Charles Frederick Hartt.

The results of this and the previous expedition were published in book form in 1870, under the title of Geology and Physical Geography of Brazil. In this work the gneisses of the Province of Rio de Janeiro are regarded as metamorphosed or sedimentary deposits and of Azoic age. Their thickness he did not even estimate, recognizing the fact that their apparent enormous thickness was due to numerous reversed folds, so that one might travel for miles over their upturned edges, finding them always highly inclined and dipping in the same general direction.

Concerning the probable age of the metamorphic rocks succeeding the gneisses he found no proof, though it was suggested they might be Silurian or Devonian. South of Rio he found unmistakable Carboniferous rocks, including beds of bituminous coal, and in the province of Sergipe, underlying the Cretaceous, a thick series of red sandstones, referred to the Triassic. No Jurassic was recognized.

Marine Cretaceous beds of undetermined extent were found north of the Abrolhos Islands, which were conformably overlaid by clays and ferruginous sandstone, referred to the Tertiary. Overlying this along the whole coast he found an immense sheet of structureless clays, gravels, and bowlder deposits, which he believed, with Agassiz, to have been the work of glacial ice, though he noted that nowhere had there been seen either polished or striated rocks, such as are almost constant accompaniments of glaciation elsewhere. It is almost needless to add that this view is no longer held by anyone, the bowlders supposed to have been erratics being merely bowlders of decomposition and their distribution the work of gravity and water.

In 1870 Hartt went again to Brazil, and in 1875, while professor of geology at Cornell University, was appointed chief of the geological commission of that country, with Richard Rathbun as assistant. He died in 1878.

H. E. Eames's Work in Minnesota, 1865-66.

An act of the State legislature of Minnesota approved March 2, 1865, provided for the establishment of a State geological survey, but one which proved short-lived. Henry E. Eames was made State geologist, and during his term of office made two brief reports of 23 and 58 pages respectively, both bearing on the title page the date of 1866. The work was almost wholly of an economic nature.

Hilgard's Views on the Drift, 1866.

Eugene W. Hilgard, in an article in the American Journal of Science for 1866, pointed out the great difference in the character of the drift in the north and northeast and that of the west (Mississippi Valley). He felt that the glacial theory alone, as then understood, could not account for these deposits north of the Ohio any more than for the Osage sand delta south of it. Though referring to Agassiz's observation regarding "the melting snow of the declining glacial epoch" and its instrumentality in forming river terraces, he adopted as more plausible the idea first announced by Toumey to the effect that the southern drift may have been formed in consequence of the sudden melting of the northern glaciers, "such as would have resulted from a first rapid depression of so large a mass of ice below the snow line." At first the flood action would be violent, producing the deep erosion of the underlying formations and the transportation and redeposition in mass of their materials. After the first rush, the stratified deposits would be formed, mingled with more or less bowlder material from floating ice. The influx of cold water from the north would, he thought, account for the absence of signs of life in the deposits. The "grandly simple means of a single elevation and redepression in the northern latitudes * * * will equally satisfy the conditions required for the formation of the western and southern drift."

Kerr's Geological Work in North Carolina, 1866-1869.

W. C. Kerr, who succeeded Professor Emmons as State geologist of North Carolina, received his commission on April 4, 1866, and continued in service until the time of his death, in 1885. His first Report of Progress, submitted in January, 1867, was an octavo volume of 56 pages, in which the purposes of the survey were set forth and a summary of the geology of the western part of the State given, so far as known. The rocks of this western area were regarded as belonging "to the most ancient of the Azoic series," and to have been above sea level since very ancient times. As with his predecessors, Kerr was troubled to account for the drift, noting that while it occurred far beyond the limits usually ascribed to glacial action, yet there were "numerous phenomena which have no other plausible explanation."

Kerr's second report, submitted in 1869, was of equal brevity, but naturally contained more of the results of the author's personal observations. He noted that the mountains, plateaus, and valleys of the French Broad and Lower Catawba areas owed "their existence and all the details of their form and position to the action of water, the basins * * * being * * * without exception, valleys of erosion, having in no case an anticlinal or synclinal origin."

The entire western portion of the State he considered as consisting of four groups or formations, first, the—

Cherokee slates along the Smoky Mountains, on the northwest border, consisting of clay slates and shales, sandstones, grits, conglomerates, and limestones; second, the Buncombe group, occupying the larger portion of the great transmontane plateau between the Blue Ridge and Smoky Mountains, and consisting of gneissic and granitoid rocks; third, the Linville slates, a narrow belt stretching for the most part along the Blue Ridge and composed, like the first group, of semimetamorphic argillaceous slates and shales, sandstones, limestone, and gneissoid grits; fourth, the Piedmont group, gneissic and granitoid.

He noted further that these four groups constituted two recurrences of the same rocks, in the same order, recalling Rogers's theory of reduplication by folding and overturns, as worked out in Pennsylvania.

John L. Le Conte, a cousin of the Joseph Le Conte, elsewhere noted, is known to science rather through his entomological than geological writings. Five papers are credited to his pen by Darton in his Catalogue and Index of North American Geology. Of these, the most important and the only one that need here be considered is one on the geology of the survey for the extension of the Union Pacific Railroad from the Smoky Hill River, Kansas, to the Rio Grande. He made a detailed study of the coal beds, and on the basis of their molluscan remains maintained that such were of Cretaceous age rather than Tertiary, as claimed by Lesquereux. His reasoning as to the relative value of botanical and molluscan remains for determining the age of beds is worthy of note. He wrote: "The difference between the plants of our early Cretaceous and those of the European middle Tertiary could be ascertained only after much discussion and by the stratigraphy of the region, and we have no right from a few resemblances in vegetables to infer the synchronism either of the western lignite beds with each other, or any of them with the European Eocene and Miocene, except when supported by paleontological evidence derived from animal remains." In this most geologists will now agree with him.

John L. Le Conte's Union Pacific Railroad Survey, 1867.

Le Conte's views, as shown in this report, concerning the general development of the western portion of the continent, indicated an ability to deal with the larger problems of geology in a philosophical and highly satisfactory manner, and it is perhaps to be regretted that he should have allowed himself to be drawn off into other pursuits. As noted, this paper was the most important of his geological writings, as it was also the last.

The second geological survey of Iowa was inaugurated in April, 1866, with Dr. Charles A. White as director, and Orestes St. John, principal geological assistant. The survey continued to the end of 1869, results being published in the form of two royal octavo volumes, comprising all told some 443 pages, with a colored geological map of the entire State.

White' Survey of Iowa, 1866-1869.

As Hall and Whitney had devoted a large portion of their attention during the previous survey to the eastern part of the State, so White devoted himself mainly to an investigation of the phenomena of the western part. He found reason, as noted in his introductory letter to the governor, to discourage all explorations for mineral oils or precious metals in the State, and also pointed out the hazard of exploring for coal beyond the northern and eastern boundaries of the coal field as designated in his geological map. He also showed that, though iron ore of a good quality had frequently been found in the State, the deposits were always limited. In all of these points he was correct.

Considerable attention was given to the peat deposits and an estimate made of the amount of material within the State limits which could be utilized for fuel purposes should occasion demand.

Among the phenomena of lesser importance he called attention to the moving of the bowlders on the shores of lakes and piling them into wall-like masses through the expansive action of the freezing water. The so-called Bluff deposit he considered to be of more recent origin than the drift, and referred it to the earliest part of the so-called Terrace epoch, the material composing it having originated by fluviatile erosion immediately upon the close of the Glacial epoch, being afterwards deposited as a lacustral sediment in the broad depression in the surface of the drift left by the retreating glaciers. He differed entirely with Whitney as to the cause of the absence of trees in the prairie region, and felt no hesitation in declaring that the real cause of the existence of the prairies in Iowa was the recurrence of the annual fires.

He divided the formations of the State into Azoic, Lower Silurian, Upper Silurian and Devonian, Carboniferous, and Cretaceous systems, and regarded the Sioux Falls quartzite, with its associated pipestone, as belonging to the Azoic. The Potsdam sandstone, which he found reaching a thickness in the State of about 300 feet, he thought to be probably overlying this Sioux quartzite. This view is generally held to-day.

White regarded it as evident that there was no hope of profitable lead mining within the limits of the State in the Lower Magnesian limestone, in this agreeing with Whitney (p. 468). For the so-called Hudson River shales of Hall he substituted the name of Maquoketa shales. All the Devonian rocks of the State he referred to the Hamilton period.

He found a strict conformability in all the rocks from the Potsdam sandstones to the Keokuk limestone, inclusive, but between this last and the rocks of the Coal Measures an unconformability and also one between the St. Louis limestone and the older formations of the sub-Cretaceous group. Instead of there being only one formation of Carboniferous limestone, as had been generally supposed, White claimed to have found two, each possessing similar lithological but different paleontological characteristics, the one overlying and the other underlying the coal-producing strata.

The various folds found in the strata of the Iowa rocks he regarded as all having taken place subsequent to the deposition of the latest strata of Carboniferous age and before any of those of Cretaceous age were deposited.

The gypsum deposits were thought to be presumably of Mesozoic age and as having originated through chemical precipitation in comparatively still waters which were saturated with sulphate of lime and destitute of life. The fact that these deposits contained no fossils rendered the exact determination of their geological age a matter of some difficulty. It is therefore well to note that Keyes in his report in 1895 refers them to the upper part of the Mesozoic—the Cretaceous.[a]

White, it should be noted, had in 1860[b] described in considerable detail the rocks and their included fossils in the vicinity of Burlington, Iowa. He identified here eight beds, the lower six of which he regarded as the equivalent of, though not necessarily contemporaneous with, the Chemung of New York. The two upper beds, which were of limestone, he regarded as Carboniferous, though he remarked that the line drawn between the two formations was largely imaginary, indicating merely the limit where the Devonian species ceased to predominate and upward from which the Carboniferous species flourished in full force.

It was suggested that the Devonian species might have originated at the east and migrated westward during the time that the bottom of the Chemung sea was gradually sinking and receiving the deposits forming the Old Red sandstone, thus making the Devonian rocks equivalent to the New York Chemung and contemporaneous, in part at least, with the Old Red Sandstone of the Catskill Mountains.[c]

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[a] Report of the State Geological Survey of Iowa, VII, 1895.

[b] Boston Journal of Natural History, VIII, 1859–1863, pp. 205–235.

[c] All of the six beds then supposed to be Devonian are now commonly regarded as belonging to the basal Carboniferous (Kinderhook).

Later (in 1866) Niles and Wachsmuth studied the upper beds, which had become known as the Burlington limestone, and were led by the crinoidal remains to regard the two divisions as two independent formations, which they designated as the Lower and Upper Burlington, a subdivision which still holds.

Safford's final report on the geology of Tennessee did not appear until 1869, having been delayed by the incidents of the civil war. It was accompanied by a colored geological map of the State, and a geological section, uncolored, extending from the Unaka chain on the east of the Mississippi, and giving, on the whole, a very comprehensive and easily understood idea of the physical geography and geology of the State, as well as its economic resources. He here called attention to the frequent recurrence of the same formation, or series of formations, met with in crossing East Tennessee, and accounted for the phenomena on the theory that the bed had been thrown into a series of parallel and closely compressed and overturned folds, the crests of which had been subsequently denuded (see p. 488).

Safford's Final Report on the Geology of Tennessee, 1869.

Fig. 79.—Charles Abiather White, Rush Emery, and Orestes St. John.

Although on his map a section of the Ocoee conglomerate was put down as belonging at the top of the Azoic series, in his chapter on the Potsdam group it was stated that the Ocoee conglomerate and slates, Chilhowee sandstones, and Knox group of shales, dolomites, and limestones might be regarded as a formation which corresponds to Dana's Potsdam period, and that it was not easy to separate, lithologically, the Ocoee subgroup from the Chilhowee, as they often run into each other.

The main bulk of the report was given up to a discussion of the distribution, lithological nature, and characteristic fossils of the various formations. He was disposed to regard the Porter's Creek group of the Tertiary as distinct from the Orange sand, this latter name having been originally provisionally applied by him to a series of strata which he regarded as, for the most part, equivalent to Hilgard's northern lignitic. The general grouping of the formations, from the Cretaceous upward, was essentially the same as had been given by him in a previous paper in the American Journal of Science (1864), and which is as follows, beginning at the bottom:

1. Coffee sand	Cretaceous.
2. Green sand or the shell bed	Cretaceous.
3. Ripley group (provisional)	Cretaceous.
4. Porter's Creek group (provisional)	Tertiary (?)
5. Orange sand or Lagrange group	Tertiary.
6. Bluff lignite (provisional)	Tertiary (?)
7. Bluff gravel	Post-Tertiary.
8. Bluff loam	Post-Tertiary.
9. Bottom alluvium	Modern.

Fifteen new species of invertebrate fossils were described. The work does not seem to have attracted much attention at the time, and was given but a half-page review in the American Journal of Science for that year. In this, attention was merely called to the fact that Safford differed with Hilgard on the question of the age of the Orange sand.

Hilgard's Work in Louisiana, 1869.

In 1869 E. W. Hilgard, acting under the auspices of the New Orleans Academy of Sciences, made a reconnaissance of Louisiana, a summary of the results of which was published in the American Journal of Science for 1869. The expense of the trip was paid partly by subscription and partly by an appropriation by the State Board of Immigration, and the time limited to thirty days. The journey (some 625 miles) was made mainly on horseback, passing Petite Anse and New Iberia on the Tèche by way of Opelousas to Bayou Chicot; thence to the Calcasieu River, down that stream to Lake Charles and the sulphur and petroleum wells, on the West Fork of the Calcasieu River; thence north to Sabine Town, Texas; thence by way of Many to Mansfield, Louisiana; thence, crossing Red River at Coushatta Chute landing to the salines on Saline Bayou, and thence, by way of Winnfield and Harrisonburg on the Ouachita River, where the expedition terminated. Among the more striking results announced was the fact that the Gulf coast has in late Quaternary times suffered a depression to the extent of at least 900 feet, and during the Terrace epoch a contrary motion to the extent of about half that amount. The occurrence of sulphur and gypsum beds was also noted. The various formations were described as: The Port Hudson group, the Orange sand formation, the Grand Gulf formation, the Vicksburg group, and the Mansfield group.

In 1869 the geological survey of Michigan, which had been brought to a close in 1861 by the outbreak of the civil war, was resuscitated through an act of the legislature, establishing a board of survey, consisting of the governor of the State, the president of the board of education, and the superintendent of public instruction, with power to select geologists, disburse the money appropriated, and perform other necessary acts. Under this law Prof. Alexander Winchell was again made director, and undertook himself the investigation of the Lower Peninsula, with the assistance of his brother N. H. Winchell, M. W. Harrington, E. A. Strong, A. M. Wadsworth, C. B. Headley, A. O. Currier, and J. H. Emerson. Later (1873–1876), after Winchell's retirement, C. Rominger was appointed by the board to work on the Lower Peninsula also.

Winchell's Survey of Michigan, 1869.

To Maj. T. B. Brooks, as a State geologist, was assigned the survey of the iron regions; to Raphael Pumpelly that of the copper regions of the Upper Peninsula, and to Carl Rominger a study of the Paleozoic rocks and their associated fossils. Brooks's report, submitted in 1873 and forming part one of the first volume of the reports of this survey, was written with the idea of making it "as complete a manual as possible of information relating to the finding, extracting, transporting, and smelting of the iron ores of the Lake Superior region." With this in view, he presented in the order here given, first, an historical sketch of the discovery and development of the iron mines; second, the geology of the Upper Peninsula, including the lithology; third, the geology of the Marquette iron region; fourth, the geology of the Menominee iron region; fifth, the Lake Gogebic and Montreal River iron ridge; sixth, a chapter on exploration and prospecting for ore; and seventh, the magnetism of rocks and use of the magnetic needle in exploring, concluding with chapters on the method and cost of mining specular and magnetic ores and the chemical composition of the ores.

The lithological work on the rocks of the region was performed by A. A. Julian, of New York, his report forming the second volume (298 pages) of the survey.

Brooks's Work.

Brooks's work contained scarcely anything of a speculative nature and but little as to the origin of the ores themselves. With reference to the association of magnetic and specular ores, he wrote:

> If we suppose all our ores to have been once magnetic, and that the red specular was first derived from the magnetite and the hydrated oxide (soft hematites) in turn from it, we have an hypothesis which best explains many facts and will be of use to the explorer.

Again, with reference to the ore of the Negaunee district:

> If we suppose tepid alkaline waters to have permeated this formation and to have dissolved out the greater portion of the siliceous matter, leaving the iron oxide in an hydrated earthy condition, we would have the essential character exhibited by this formation as developed on the New England, Saginaw range, and, as will be seen afterward, at the Lake Superior mine. This is offered not so much as an hypothesis to account for the difference as to illustrate the facts observed.

This view, so modestly put, contains in it, however, the germ of the conclusions arrived at by Van Hise some twenty-five years later.[a]

He noted the monoclinal character of the deposit at the Washington mine property in the Marquette region, and described the ore of the Lake Superior specular and hematite workings and the Barnum mine as occupying the position of "the frustum of a hollow cone lying with its axis horizontal and its small end toward the east," which had been cut in two by a horizontal plane representing the surface of the ground.

Other points, which it is well to note, since Rominger in his later report had occasion to disagree with him, are his regarding the ores of the Cascade Range as the equivalent of the Michigan and magnetic ores of the Mishigami district and as older than any of the iron beds in the Republic Mountain series; and, second, the Felch Mountain ore deposit as belonging to the lower quartzite, the ore itself resting immediately upon and being bounded on the south by hornblendic, micaceous, and gneissic rocks which are undoubtedly Laurentian. Subsequent studies by Wadsworth, Van Hise, and others have shown him to be substantially correct in both of these conclusions.

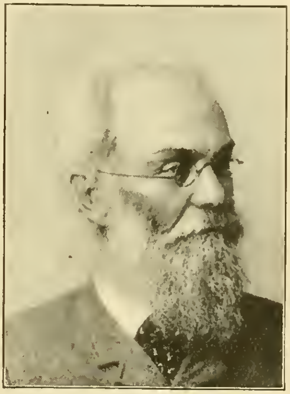
Fig. 80.—Thomas Benton Brooks.

Ill health prevented Brooks from carrying out his work in as thorough a manner as he wished, and his letter of transmittal was written from London, he having gone abroad to recuperate.

Brooks, as may readily be inferred, was an eminently practical man. Indeed, his entire training was of a practical nature, consisting of two years at the School of Engineering of Union College and a single course of lectures on geology under Lesley at the University of Pennsylvania. His early work was in connection with land surveys, but after his retirement from the Army in the fall of 1864 he served a year on the geological survey of New Jersey under Cook, and then in 1865 became vice-president and general manager of the Iron Cliff mine, near Negaunee, in the Marquette district of Michigan. Here he began that geological work upon which is mainly based his reputation. The difficulties which he encountered were such as can be scarcely comprehended by those who have not visited the region. The country was, much of it, heavily forested and swampy as well. Outcrops were few and perhaps wholly obscured by the drift or by undergrowth. There were no maps,

Sketch of Brooks.

[a] Monograph No. XXVIII, U. S. Geological Survey, 1897.

or, at best, the very poor ones furnished by the Land Office, no railroads, and transportation was limited to canoes and pack animals. There were few prospect holes and fewer developed mines. To these difficulties were added the complications due to repeated folding and squeezing which the beds had undergone. Yet Brooks, by his persistency and originality in methods, succeeded in producing a work of value as a scientific production as well as of the greatest use to the prospector—a rare combination, indeed—and a work which has been superseded only by one that it took twenty years of study by an able corps of geologists and a hundredfold better facilities to produce.

Brooks devised the dial compass and adapted the dip needle to the purposes of the prospector. Persistent and determined to succeed in spite of the poverty of appropriations, he expended over $2,000 of his own means and, worst of all, sapped his own vitality in the work to the extent that he became a confirmed invalid before reaching middle age.

As already intimated, his health gave out in 1873 and he sought relief abroad, residing in London and Dresden, where his reports were completed. After his return to this country in 1876, he resided at Monroe and Newburgh, New York, and after 1883, during the winters, at Bainbridge, Georgia, living the life of a country gentleman and farmer.

Pumpelly's Work in Michigan, 1869-1873.

Pumpelly's work in the copper district is of interest on account of his theories regarding the origin of the copper and the age and lithological nature of the copper-bearing rocks. The conclusions at which he arrived were as follows:

First, the cupriferous series was formed before the tilting of the Huronian beds upon which it rests conformably, and consequently before the elevation of the great Azoic area, whose existence during the Potsdam period predetermined the Silurian basins of Michigan and Lake Superior. Second, after the elevation of these rocks and after they had assumed their essential lithological characteristics, came the deposition of the sandstone and its accompanying shales, as products of the erosion of these older rocks, and containing fossils which show them to belong to the Lower Silurian, though it is still uncertain whether they should be referred to the Potsdam, Calciferous, or Chazy.

A chapter was given on the paragenesis of copper and its associates. With reference to these subjects he wrote:

It is still an open question whether the trap which formed the parent rock of the melaphyr was an eruptive or a purely metamorphic rock. If it was eruptive, it was spread over the bottom of the sea in beds of great regularity and with intervals which were occupied by the deposition of the beds of conglomerate and sandstones. It should seem probable that the copper in the melaphyrs was derived by concentration from the whole thickness of the sedimentary members of the group, including the thousands of feet of sandstones, conglomerates, and shales which overlie the melaphyrs, and including melaphyrs also.

The translocation he regarded as having been initiated by the sulphate of copper resulting from the oxidation of the sulphide, but as this salt must have been soon decomposed by the abundant acid carbonate of lime, he could not suppose it to have been effectual in the final concentration of the large deposits, and he thought it more probable that this last was accomplished by the more permanent solution of carbonate and silicate of copper.

Pumpelly was assisted by A. R. Marvine, L. P. Emerson, and S. B. Ladd.

Rominger's report on the Paleozoic rocks of the Upper Peninsula formed part 3 of the third volume of the Survey reports (1873). His second appeared in 1876, forming one of the four large octavo volumes of the Survey, comprising altogether some 386 pages, with 55 plates of fossils, and a colored geological map of the area surveyed. The geological portion contains a record of the characteristic rocks, their geographical distribution, and the fossils they contain. It is to be noted that Rominger showed a disposition to disagree in many of his conclusions with Winchell, Brooks, and others who had preceded him.

C. Rominger's Work in Michigan, 1873–1876.

The presence of large bowlders in the midst or on top of well-stratified drift layers he conceived to be due to the transportation of the material by means of swimming icebergs during periods of flood. In this he agreed, substantially, with Dawson, of the Canadian Survey. The dolomites of the Ida quarries, which Winchell identified as belonging with the Onondaga salt group (Upper Silurian), he considered as Upper Helderberg (Middle Devonian), and he stated that the mapping by Winchell of Upper Helderberg rocks throughout a great portion of Cass, Van Buren, and all over Berrien County, was an error. He also differed with Winchell regarding the stratigraphic position of the Hamilton rocks of Big Traverse Bay. Winchell's Huron shales he considered from paleontological evidence, to be identical with the Cuyahoga shales of the Ohio geologists, and, therefore, belonging to the lower part of the Carboniferous rather than the Upper Devonian. He also accused Winchell of a peculiar stratigraphic blunder in preparing a section west of Flat Rock:

> Unfortunately this section is laid across a synclinal undulation of the formation, and begins at one end with the same rock beds (Marshall sandstone), which on the other end are found very near the base. Under the impression that he was all the while descending, he stands again on the horizon from which he started.

The salt brines of the State, according to Rominger, are derived from rocks of the Waverly group, and not from those of a higher horizon, which Winchell had designated as the Michigan salt group.

Rominger also made reports on soils, building stones, and slate quarries, and on the Ontonagon silver mining district. What is perhaps the most valuable part of the report is that relating to the fossil corals, which was, for its time, unsurpassed.

Subsequently (1881) Rominger, still acting as a State geologist (1878-1880), issued a report on the Upper Peninsula, which dealt almost entirely with the economic problems of the iron region.

He regarded the region about Marquette as—

a synclinal trough of granite which, by the upheaval of its northern and southern margins, caused the inclosure of the incumbent sedimentary strata between its walls and their simultaneous uplift and corrugations into parallel folds by the lateral pressure from its rising and approaching edges.

Concerning the origin of the iron ores of the Upper Peninsula, he wrote:

These ore deposits are not regular sedimentary layers originally formed of iron oxide in a state of purity, but are evidently the product of decomposition of the impurer mixed ferruginous ledges by percolating water, leaching out the siliceous matter and replacing it by the deposition of oxide of iron held in solution.

This view is not greatly different from the conclusion reached by Brooks, as already noted, and subsequently by Van Hise.

FIG. 81.—Carl Rominger.

His views as to the origin of serpentinous rocks were not at all clear. Writing with particular reference to those of Presque Isle, he remarked that they occur—

generally in bulky, nonstratified masses which, if they ever originated from mechanical sedimentary deposits, are by chemical action so completely transformed as to efface all traces of their former detrital structure. They resemble volcanic eruptive rocks forced to the surface in a soft, plastic condition, and most likely heat was one of the prime agents in their formation, or else transformation, in combination with aqueous vapors.

Rominger, in his first report, that on the Paleozoic rocks of the copper district, took the ground that the Silurian age of the Lake Superior sandstone was unequivocally proved by its stratigraphical position. This is the view now generally held, though the Potsdam period, to which the beds are referred, is now considered as the upper part of the Cambrian instead of the Lower Silurian, as at that date.

Sketch of Rominger.

Rominger's career, like that of Lesquereux and others that might be mentioned, offers an interesting illustration of the difficulties with which the early naturalists had to contend, particularly when foreigners and but little acquainted with the language of their adopted country.

Born in Wurtemberg, he came to America in 1848 on account of revolutionary disturbances, and without previous preparation. Though trained as a physician and geologist, yet his poor command of English he felt excluded him from associating with scientific men, and, being without financial resources, he established himself as a physician in Cincinnati, a city containing a large German population. Here he remained for twenty-five years, improving himself in the language and devoting what time could be spared from his professional duties to the study of paleontology and geology. In 1870, through the influence of James Hall and others, he was appointed one of the geologists of the Michigan survey under Winchell, ultimately himself becoming director, in which position he remained until 1883, when, under a new administration, he was removed to make room for another.

His bibliography, although not numerous, is important, particularly that relating to paleontological matters. It had been his intention to continue his work on the fossil corals, but the political changes above mentioned prevented. The edition of his work issued by the State being insufficient to supply the demand, Rominger had printed 250 copies at a personal expense of $4.75 each, hoping to be able to sell them at least for the same figure. But this proved impossible, and he suffered a direct loss thereby of not less than $800.

A second geological survey of Ohio was inaugurated in 1869, and J. S. Newberry appointed chief geologist. This survey was continued in operation until 1878, when it was discontinued, owing to a disagreement between Dr. Newberry and the legislature (see p. 481), by withholding the appropriations.

Newberry Survey of Ohio, 1869–1878.

During the period of its existence two annual reports and four volumes of a final report were published, the latest bearing on the title-page the date of 1882. Of these the first volume was given up to geology,[a] the second and third to paleontology, and the fourth to zoology and botany. The first volume was, however, issued in two parts, of which Part I only was strictly geological, and Part II paleontological. A third paleontological volume to be devoted to the Carboniferous flora was projected but never appeared, owing to failure of the legislature to make the necessary appropriations.

Newberry's principal assistants in 1869 were E. B. Andrews, Edward Orton (who afterwards became State geologist), and John H. Klippart. In 1870 the force was increased by the employment of T. G. Wormley as chemist, and G. K. Gilbert, M. C. Read, Henry Newton, and W. B. Potter as local assistants. As one of the results of their investigations it was announced that the so-called Cliff limestone had been resolved into seven distinct formations belonging to the two great geological systems—the Devonian and Upper Silurian. The discovery of Oriskany sandstone in the northwest quarter of the State was announced and the Carboniferous age of the rocks of the Waverly group thought to have been established on paleontological evidence. This has, however, been since shown to be erroneous.

[a] An edition of 2,000 copies of this report was printed in the German language, as were also the annual reports of Rogers's Survey of Pennsylvania.

Beginning with the later Tertiary times, the following sequence of events was established:

(*a*) In the Miocene and Pliocene epochs a continent several hundred feet lower than now, the ocean reaching to Louisville and Iowa, with a subtropical climate prevailing over the lake region, the climate of Greenland and Alaska being as mild as that of southern Ohio is now, while herds of gigantic mammals ranged over the plains.

(*b*) A preglacial epoch of gradual continental elevation which culminated in the glacial epoch, when the climate of Ohio was similar to that of Greenland at present, and glaciers covered a large part of the surface down to the parallel of forty degrees.

(*c*) This period was followed by another interval of continental subsidence characterized by a warmer climate and melting of the glaciers and by inland fresh-water seas filling the lake basin, and in which were deposited the Erie and Champlain clays, sands, and bowlders.

(*d*) Another epoch of elevation which is still in progress.

Much attention was given to economic geology and the study of the coal beds. From analyses it was shown that the change from woody tissues to peat or lignite, and thence to bituminous and anthracite coal and plumbago consisted in the evolution of a portion of the carbon, hydrogen, and oxygen, leaving a constantly increasing percentage of carbon behind. This evolution Newberry conceived to be due to the disturbances which resulted in the uplifting of the mountain chains and metamorphosed the included rocks.

The coal beds of Ohio, it should be noted, were considered as always having been separated from those of Illinois by the Cincinnati anticline. This Cincinnati uplift or arch was, in the report for 1869, regarded as having formed a land surface over a considerable portion of its length at least during the earlier and probably throughout all the Devonian ages. Later, in discussing the work of Orton in Adams County, Newberry wrote:

> Here we have an indubitable record of the elevation of the Cincinnati arch between the Upper and Lower Silurian ages, and proof that it is far older than the Appalachian system, with which it has been commonly associated.

The carbonaceous matter of the Huron shales was suggested as probably due to an abundance of seaweeds which flourished in a kind of Saragossa sea which occupied that region during the period of deposition.

The petroleum and gas filling the cavities and interstices in the sandstones and conglomerates in the Oil Creek region were regarded as not indigenous to those rocks, but rather as originating in the lower-lying Huronian shales, from whence they had been forced upward by hydrostatic pressure.

The dolomitic character of the rocks of the Clinton, Niagara, and Water-lime series was ascribed to "a vital rather than a chemical or physical cause," and the occurrence of a large percentage of magnesia in the hard parts of some groups of marine invertebrates, as the Millipores, cited as a possible explanation of the origin of the rock, in this following a suggestion made by Dana in the report of the Wilkes Exploring Expedition.

The sheet of clay and bowlders which was found directly overlying the polished surface of the rocks over so large a part of the State, and which is now known as till and bowlder clay, was described under the name of glacial drift, while the loose bowlders which are indiscriminately scattered over the State, frequently resting on the fine stratified clays, were known under the name of "iceberg drift."

Newberry conceived that, during the latter part of the glacial period, a great inland sea of fresh water filled the basins before occupied by ice, the northern shore of which was formed by the ice wall at the foot of the glacier. The mud which was brought into this lake through the grinding action of the glacier and there deposited formed the so-called Erie clays.

FIG. 82.—Charles Whittlesey.

For the rocks of the so-called *blue limestone* series of the early geological surveys he adopted the name Cincinnati group, as first applied by Meek and Worthen. The gypsum of the Salina group was regarded as precipitated in continuous sheets and not to have resulted from a change in the ordinary limestones by sulphuric acid, as had been claimed for the gypsum beds of New York. This is the view now commonly accepted.

It appears that Colonel Whittlesey was an aspirant for the position of State geologist at the time of Newberry's appointment, and to judge from the tone of an article by Newberry published in the Cincinnati Commercial,[a] adopted rather unfair means to throw discredit upon the latter's work. In his reply Newberry was very bitter, stating that whatever may have been his own qualifications for the work, Whittlesey was too old and in too poor health to do good work, and also that he was not a good geologist; that, further, he held to certain geological heresies which would impair his work; that he believed in the mineral origin of coal, and that the brown hematite ores of the Alleghenies were interstratified with the limestones instead of being mere pockets. He further claimed that Whittlesey was no paleontologist, and without paleontology no man could be a good geologist. As an illustration of his deficiency in this respect, Newberry referred to his (Whittlesey's) paper on the

The Newberry-Whittlesey Controversy, 1870.

[a] March 28, 1870.

Equivalency of the Rocks of Northeastern Ohio, in which he identified certain rocks as equivalent with the Chemung, Portage, and Hamilton groups, of New York, on paleontological grounds, whereas in fact every one of the twelve species of fossils on which this identification was based was wrongly named, the fossils actually being wholly of Carboniferous age.

Andrews's Views on the Glacial Drift, 1869.

Dr. E. Andrews, who was one of Newberry's assistants on the Ohio geological survey, in the American Journal of Science for 1869, wrote on the western bowlder drift, and took the ground that the fresh-water submergence which deposited the loess was not a continuation of the drift action, but was in that region separated from it by a tranquil period during which the rivers were down within their banks. As a whole, the western drift was, he thought—

> beyond all question a stratified water deposit. A study of the cliffs eroded by the lakes, showing both modified and unmodified drift, has obliged those western geologists most familiar with the sections to abandon the glacial theory and admit that the bowlder drift of this region is altogether an aqueous deposit, though the waters floated vast quantities of ice.

He described the occurrence of bowlders of loose gravel, sometimes 3 feet in diameter, in the clay passed through in digging the tunnel under the lake for the Chicago waterworks extension. Such he regarded as masses of frozen gravel dropped from floating ice. With reference to the gravel deposits on the peninsula between Green Bay and Lake Michigan, covering an area of 4,000 square miles, he wrote:

> The stratified character of the gravel * * * is on the whole too evident to admit of any possible doubt. * * * It would seem to be an unavoidable inference that our drift of this region not only came from the north, but it came in a vast sweep of water deep enough to cover gravel hills more than 800 feet high, and with velocity enough to throw such coarse material into lofty steeps and summits.

Again, concerning the absence of drift on the north slope of the Laurentian hills and the scratched and "pounded" aspect of the region, he wrote:

> We seem, therefore, to have testimony that the drift action for a thousand miles east and west along the Laurentian crest and to an unknown distance north of it was too violent to admit of drift deposits, even the bowlders being swept off.

The finer character of the material in northern and central Illinois he thought to be due to the less violent rush of the waters. These waters he imagined to have been drawn off suddenly after the deposition of the Orange loam, thus accounting for the absence of beach lines.

These views are not quite those of Newberry himself, as expressed in a paper before the New York Lyceum in 1870. From facts observed in the basin of the Great Lakes and the Valley of the Mississippi, he argued that, synchronously with the glacial epoch of Europe, the northern half of North America had a climate comparable with that of Greenland, and that, as a result, glaciers were formed, the direction of flow of which corresponded in a general way with the present drainage channels. The Lower Mississippi he looked upon as a "half-drowned river"—that is, one with its lower channel deeply submerged and silted up, an unmistakable proof that at that period the country stood at a considerably greater elevation than at present.

Newberry's Views on the Drift, 1870.

The trough of the Mississippi, to his mind, was simply a valley of erosion which, since the close of the Carboniferous period, had been traversed by a river which drained the area of the northern Mississippi, the Ohio, and the Tennessee, and, since the Miocene period, the Missouri, Arkansas, and the Red rivers as well. Through alternate elevation and depression the mouth of the stream had varied its position from time to time to the amount of a thousand miles, the final long-continued depression being the primary cause of the climatic amelioration which brought the glacial period to an end.

The fine blue-gray and highly plastic so-called Erie clays and their accompanying sands and bowlders were to him due to floating icebergs during a period of continental depression and great inland seas, deposited, in fact, just as similar materials are conceived as now being scattered over the sea bottoms about Newfoundland:

If we restore in imagination this inland sea, which we have proved once filled the basin of the lakes, gradually displacing the retreating glaciers, we are inevitably led to a time in the history of this region when the southern shore of this sea was formed by the highlands of Ohio, etc., the northern shore a wall of ice resting on the hills of crystalline and trappean rocks about Lake Superior and Lake Huron.

From this ice wall masses must from time to time have been detached, just as they are now detached from the Humboldt glacier, and floated off southward with the current, bearing in their grasp sand, gravel, and bowlders—whatever composed the beach from which they sailed. Five hundred miles south they grounded upon the southern shore—the highlands of now western New York, Pennsylvania, and Ohio, or the shallows of the prairie region of Indiana, Illinois, and Iowa. There melting away and depositing their entire loads, as I have sometimes seen them, a thousand or more bowlders on a few acres, resting on the Erie clays and looking in the distance like flocks of sheep, or dropping here and there a stone and floating on east or west till wholly dissipated.

The loess, as one would naturally expect from the foregoing, was looked upon as the finer sediment deposited in the quiet waters of one of these inland seas, to which the icebergs had no access. The lake basins, with the exception of that of Lake Superior, which is a synclinal trough, were regarded as excavated by glacial action and once much deeper than now, having become partially filled with drift deposits as they gradually emerged. Temporary pauses in the period of uplift would give time for wave action, and thus would be formed the terraces and ancient beaches so commonly found in the lake regions.

Newberry was succeeded as State geologist by Edward Orton, who had previously acted as chief assistant. During Orton's administration certain "pardonable errors in identification," which left the stratigraphy of the coal series of Ohio in an almost hopeless tangle, were corrected. He showed the stratigraphical order of the lower Coal Measures of Ohio to be completely in harmony with that of Pennsylvania and that the entire series could be traced from the eastern margin of the State clear across the same to Kentucky. This is regarded by White, Orton's biographer, as the masterpiece of Doctor Orton's purely geological work, although his contributions to the geology of petroleum and natural gas in the sixth volume, 1888, are of almost equal importance.

Orton's Appointment as State Geologist, 1882.

Orton's work during his whole life was largely of an economic character, the more important and comprehensive publications being Volumes V (1884) and VI (1888) on the Economic Geology of Ohio, his Report on Petroleum and Gas in Ohio (1890), and the Report on the Occurrence of Petroleum, Natural Gas, and Asphalt Rock in Western Kentucky (1891). He also had an important paper on the Trenton limestone as a source of petroleum and inflammable gas in Ohio and Indiana, in the Eighth Annual Report of the U. S. Geological Survey (1886–87). Aside from his record as president of the university and a teacher, Orton will be best remembered for his work on the subjects of gas and petroleum, although in his report on the third geological district he makes important observations on the Cincinnati uplift or axis, showing it to have been a slow and gradual formation resulting in a gentle flexure in the earth's crust involving the Lower and Upper Silurian and, to some extent, the Devonian formations of the State. In his own words, his conclusions were as follows:

> First, the Cincinnati axis in southern Ohio was raised above the sea at the end of the blue limestone period, or certainly early in the history of the Clinton epoch. Second, it underwent various oscillations, but the elevatory movements succeeded those of depression. Third, the rate of movement was exceedingly slow.

His views on the glacial period, expressed briefly and in his own words, were as follows:

> The following threefold divisions of glacial time may be considered as demonstrated: First, an age of general elevation of northern land accompanied by intense cold and the formation of extensive continental glaciers. Second, a general depression of the land with the return of a milder climate. Third, a partial reelevation of the land and a partial return of the cold climate, producing local glaciers and icebergs.

Orton was born in Delaware County, New York, and educated at Hamilton College, graduating in 1850. He subsequently studied at Harvard and then entered the Andover Theological Seminary, being licensed to preach in 1855, and soon after ordained as pastor of the Presbyterian Church at Downsville, Delaware County, New York. He resigned this position in order that he might accept that

EDWARD ORTON.

Professor of Geology, Ohio State University, and State Geologist of Ohio.

of professor of natural sciences in the New York State Normal School at Albany. Becoming convinced, however, that his gradually changing views on religious matters were such that he could not conscientiously continue to hold this position, he resigned it, and accepted the principalship of an academy at Chester, in Orange County, the same State.

Sketch of Orton.

In 1865 he became principal of the preparatory department of Antioch College in Ohio, then professor of natural sciences, and afterwards president of the same institution.

His active work as a geologist received its first recognition in 1869, when he was appointed Newberry's assistant. In 1873 he was made president of the new Agricultural and Mechanical College, founded under the Morrill act, and also took charge of the chair of geology in the same institution. Under his efficient administration, which lasted until 1881, the institution prospered and finally developed into the Ohio State University.

In 1882, after his voluntary retirement from the State University, the geological survey was organized and Orton made State geologist, a position he continued to hold until the time of his death in 1899.

Orton belonged to the generation beginning work immediately after the civil war and, according to his biographer, always leaned toward the application of the science to the benefit of his fellow men. "He was painstaking and exact in observation, scrupulous in statement, cautious in speculation." He was one of the first to recognize the possibility of the exhaustion of the supply of petroleum and natural gas, and to issue appeals to the people of Ohio, urging care in husbanding their resources. But these were not received in the spirit in which they were offered, and he had the melancholy satisfaction of seeing his forebodings justified by the event.

By those who knew him Orton will be remembered as always a man of perfect courtesy, dignified, a little stately, and never effusive. His life was full of considerate and helpful kindness - modest and retiring to an unusual degree, and yet one of the few men to whom honors come notwithstanding. In 1891 he suffered from a paralytic stroke which cost him the entire loss of the use of the left hand, yet he continued to teach and to work until almost the last hour of his life. For eight years he had looked upon death as a thing momentarily to be expected. He met it bravely, cheerfully, and fearlessly on October 10, 1899.

In 1869 the fourth attempt at a systematic geological survey of Indiana was made, the appointment as State geologist going this time to E. T. Cox, heretofore known to geological fame only through his work while assistant to Owen in Kentucky and Arkansas in 1856–1860.

Annual reports were issued for each of the ten years which marked the life of this survey. Those of 1869 and 1872 were accompanied by county maps, though no geological map of the State in its entirety was furnished. A colored section across the State from Greencastle to Terre Haute accompanied the report for 1869.

Cox's Survey of Indiana, 1869-1879.

Cox was assisted during the entire or a part of the time by Frank H. Bradley, Rufus Haymond, G. M. Levette, B. C. Hobbs, R. B. Warder, W. W. Borden, M. N. Elrod, John Collett, and E. S. McIntire, the fossil flora being described by Leo Lesquereux and the fauna of Wyandotte Cave by E. D. Cope. Zoological and botanical subjects were treated by D. S. Jordan, J. M. Coulter, and J. Schenk.

These reports as a whole contained little new or impressive. In the eighth, which was the most comprehensive thus far issued, Cox himself called attention to the fact that the geological history of the State "appears tame and devoid of the marvelous interest which attaches to many other regions, and that there is not a single true fault or upward or downward break or displacement of the strata thus far discovered." The oldest rocks of the State were found in the southern portion, extending from the Ohio River near the mouth of Fourteen Mile Creek to the eastern boundary line. These are the so-called Hudson River rocks of Hall, which Cox correlated with Safford's Nashville group, and which Worthen and Meek had included under the name of Cincinnati group. He regarded the Silurian strata as uplifted, not by a local disturbance, but "by an elevating force that acted very slowly and extending over the entire central area of the United States." The seat of greatest force, he thought, however, was not limited to southwestern Ohio, but was to be looked for in Kentucky.

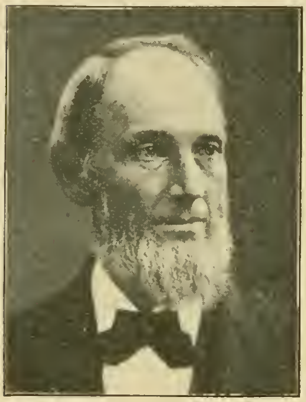

FIG. 83.—Edward Travers Cox.

Cox accepted the general theory of glacial drift as at present understood, and conceived that the climatic changes might be due to the relative position of land and water, possibly a change in the course of the Gulf Stream. He could find no evidence of a subsidence of the land to terminate the glacial period, nor could he find in Ohio, Indiana, or Illinois anything to militate against the commencement of a glacial period in Tertiary times and its continuation—

> until brought to a close by its own erosive force, aided by atmospheric and meteorological conditions. By these combined agencies acting through time the mountain home of the glacier was cut down and a general leveling of the land took place.

This suggestion that the glacial epoch worked out its own destruction through a process of leveling, whereby the altitudes which gave it birth were so far reduced that glaciers could no longer exist, is unique and, so far as the present writer is aware, original with Cox.

Upon the recommendation of Logan, Dr. A. R. C. Selwyn, an Englishman, for several years connected with the geological survey of Great Britain under De la Beche, and from 1852 until 1869 director of the geological survey of Victoria, Australia, was, upon the retirement of the first named, made director of the geological survey of Canada. In this capacity Selwyn served for twenty-five years, or until 1894. He was assisted by H. H. Ami, Elkanah Billings, and J. F. Whiteaves, paleontologists; Robert Bell, George M. Dawson, James Richardson, and J. B. Tyrrell, geologists, and B. J. Harrington and T. Sterry Hunt, chemists. With this efficient corps the work of the survey was pushed vigorously, but, extending as it did beyond the time limits laid down for this sketch, it can be touched upon but briefly.

Survey of Canada under Selwyn, 1869–1894.

Fig. 84.—Alfred Richard Cecil Selwyn.

During the period of his administration twenty large annual reports were issued and nine volumes on paleontology and paleobotany. The work of the survey was pushed westward as far as British Columbia, and though ever with economic ends in view, much was accomplished in the way of pure science. The gold fields of Nova Scotia were investigated and the silver deposits of Thunder Bay, on Lake Superior. The stratigraphic problems involved in Logan's "Quebec group" also received attention. His aim from the start, as stated by one of his biographers, was to make the survey an eminently practical department in which the records of the mines and mineral statistics should be kept for the use of both the Parliament and the public.

Selwyn is pictured to us as a scholar of rare ability, social, amiable, and chivalrous in private life, but a strict disciplinarian; tall, graceful, quick, and alert, of a rather highstrung and nervous disposition, and with a keen and observant eye. His bibliography consists mainly of short papers and summaries published in connection with his official reports.

CHAPTER VII.

THE ERA OF NATIONAL SURVEYS OR FIFTH ERA OF STATE SURVEYS, 1870–1879.

The period of the civil war had brought to light a considerable number of men for whom the piping times of peace, even when varied by Indian outbreaks in the West, afforded insufficient opportunities. They were men in whom the times had developed a power of organization and command. They were, moreover, men of courage to the point of daring. It was but natural, therefore, particularly when the necessity for military routes in the West and public land questions were taken into consideration, that such should turn their attention toward western exploration. Further, the surveys made in the third decade, in connection with routes for the Pacific railroads, and the work done by Evans, Hayden, and Meek in the Bad Lands of the Missouri, had whetted the desires of numerous investigators. Willing workers were abundant and Congress not difficult to persuade into granting the necessary funds. Hence expedition after expedition was organized and sent out, some purely military, some military and geographic, with geology only incidental, and others for the avowed purpose of geological research.

Under such conditions was inaugurated the work which culminated, in 1879, in the organization of the present U. S. Geological Survey, which, for breadth of scope and financial resources, is without counterpart in the world's history of science.

The more important of the expeditions above referred to, as will be seen, were Hayden's Geological Surveys of the Territories; King's Geological Survey of the Fortieth Parallel; Powell's Surveys of the Grand Canyon of the Colorado and adjacent regions; and Wheeler's Geographical Surveys West of the One-hundredth Meridian.

These expeditions demanded men in the prime of life and bodily vigor—men who could endure exposure and fatigue and, if necessary, face danger. It is a natural consequence that there should be found among the workers many names and faces which have not heretofore appeared in our chronicles. Among those who appear now, if not for the first time, at least for the first time prominently, mention may be made of C. E. Dutton, S. F. Emmons, G. K. Gilbert, Arnold Hague, W. H. Holmes, Clarence King, O. C. Marsh, A. R. Marvine, A. C. Peale, J. W. Powell, I. C. Russell, Orestes St. John, J. J. Stevenson, and R. P. Whitfield.

Although this was a period of great activity on the part of the General Government, State and provincial governments were by no means quiescent. Important work was being done by T. C. Chamberlin in Wisconsin, J. W. Dawson in Nova Scotia, W. C. Kerr in North Carolina, Eugene A. Smith in Alabama, and J. D. Whitney in California. There were also organized a second geological survey of Pennsylvania, with J. P. Lesley at its head, and a geological and natural history survey of Minnesota, under N. H. Winchell. Both of these last-named organizations continued their work beyond the period of the limit set for this history. An attempt at establishing a geological survey of Georgia in 1874 resulted in the appointment of George Little as State geologist and the subsequent issuance of two reports comprising altogether but 52 pages.

Fig. 85.—George Little.

Murrish's Work in Wisconsin, 1870.

In 1870 (?) John Murrish was appointed by Governor Lucius Fairchild, of Wisconsin, commissioner of the survey of the lead district of that State. Murrish was, according to his own statement, "a practical man" and had served an apprenticeship in the mines of Cornwall, going through the regular course of practical training for a miner's occupation and a miner's life. Under these conditions, it is perhaps scarcely just to compare his writings with those of men who have had better opportunities and training. Nevertheless, as he had to do with the survey of an important mining region, it is impossible to ignore the work here.

Under the title of Report of the Geological Survey of the Lead Regions, Murrish published his observations in the form of a pamphlet of 65 pages, in which he set forth his views of the various geological phenomena. He thought to have discovered that the lead-bearing fissures were grouped into ranges, the various ranges forming themselves into four well-defined belts running parallel to each other. The lead veins, according to his theories, occurred along the elevation of the land running in a generally north-and-south direction, the elevation itself being "a line of physical disturbance." Concerning the character of this physical disturbance he was not perfectly clear, but he did not regard it as due to an active volcanic disturbance nor earthquakes in the ordinary meaning of the terms.

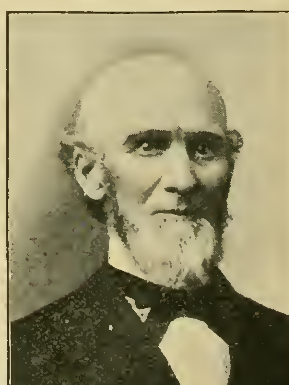

Fig. 86.—John Murrish.

He described sink holes and what are evidently stylolites, the true character of which he did not recognize, but regarded as doubtless due to the same physical disturbances. The elevation referred to and the belts of mineral land in the district were formed, he conceived, from groups of fissures or faults in the Plutonic and Azoic rocks beneath, which were themselves produced by mechanical forces evidently generated by internal heat. Water entering between the beds would percolate downward through these lines of fracture, where it would come in contact with intensely heated matter under a pressure of several hundred feet of overlying rock. If the temperature was sufficient the water would be converted into steam or elastic vapor, which might possess sufficient mechanical power to bring about the elevation. During the early formation of the stratified rocks, particularly the Potsdam sandstone, the resistance to this expansive force would be comparatively little, since vent for the steam would be easily found through the loosely accumulated sand; but as layer after layer was added to the strata and the more compact limestone began to form and harden above it, resistance would increase until to overcome it a general lifting of the strata would take place, by which escape would be effected through fissures in the rock along the line of those original faults in the Plutonic rocks below.

A microscopic examination of the sand grains from the disintegrated Potsdam sandstone having revealed the crystalline nature of the granules, due, as we now know, to the deposition of interstitial silica, he conceived, as did Whitney (p. 469), that the entire deposit was of chemical origin.

Supposing Iceland should be submerged to a considerable depth beneath the ocean, and those plains situated about 30 miles from that noted volcano Hecla, known now to be full of heated springs, steaming fissures, and boiling geysers, whose waters hold a large amount of silica in solution that is now being deposited on the surface around those places, were pouring their waters into the ocean above, should we not have there on a small scale what perhaps existed on a very large scale during our sandstone formation?

Perhaps so. Who shall say?

Like many men of slight training, Murrish failed to give proper weight to the evidence gathered and was led into many errors, the most serious of which was that of assuming that the Lower Magnesian limestone might prove to be an ore-bearing stratum—this in spite of the opinion to the contrary held by Hall, Whitney, and others.

Marsh's Scientific Expedition, 1870.

During the summer of 1870 O. C. Marsh, professor of paleontology in Yale College, began a series of scientific expeditions into the western part of the United States, having for his primary object the collection of vertebrate fossil remains. The results of these expeditions soon placed Marsh among the leading vertebrate paleontologists of the world.

The Middle West, it should be remembered, was at that time an almost unknown territory, traversed by but a single railroad (the Union Pacific), and much of it rendered unsafe for the white man through roving bands of Indians, necessitating military escort in many instances.

The first expedition explored the Pliocene deposits of Nebraska, the Miocene of northern Colorado, and the Eocene of the Bridger Basin in Wyoming and the Uinta Basin of Utah. These expeditions were supported largely at Professor Marsh's private expense, until the organization in 1879 of the U. S. Geological Survey under Powell, shortly after which Marsh was appointed a United States paleontologist, though still drawing upon his own resources when necessary or when, in his opinion, it became advisable in order that new discoveries might become immediately available.

Under these joint agencies there was brought together the mass of material now forming the vertebrate collections at Yale University and the extensive Marsh collection in the National Museum in Washington, which has formed the basis for the numerous monographs and papers included in Marsh's extensive bibliography.

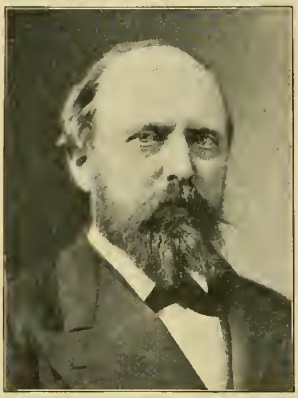

FIG. 87.—Othniel Charles Marsh.

The most noted of his early discoveries was that of the toothed birds, Odontornithes (Hesperornis and Ichthyornis), which formed the basis of a monograph published in 1880. Based on later discoveries were his monographs on the Dinocerata and the extraordinary dinosauria, of which the Anchisaurus, Brontosaurus, Laosaurus, Ceratosaurus, Camptosaurus, Stegosaurus, Claosaurus, and Triceratops are the best known representatives.

Marsh's connection with the United States Survey continued up to the time of his death, which took place in March, 1899, and much of his work lay beyond the time limits of this history.

In 1870 again the legislature of Missouri passed an act for the establishment of a mining bureau, the board of control of which was to be composed of the governor and nine members, one from each Congressional district. Upon this board was conferred the power of appointing a State geologist, the choice for which fell upon Albert Hager, of Vermont.

Hager's Work in Missouri, 1870.

Hager's term of service was, however, short, and but one report of progress published, owing to a disagreement with the board. This report dealt largely with the condition of the survey at the time he took charge. It would appear that, since the suspension of Swallow's survey in 1861, the collections and other materials, the property of the survey, had been stored in the University building at Columbia, which was at one time in the possession of armed troops, and the materials suffered accordingly, as would naturally be expected. He found, however, reports of B. F. Shumard made during the work of Swallow's survey, in a fairly complete condition. These were on the counties of Crawford, Clark, Cape Girardeau, Phelps, Ste. Genevieve, Ozark, Douglas, Perry, Jefferson, Laclede, Pulaski, and Wright. The reports of Swallow and Meek were also in a satisfactory condition. It is stated, too, that he obtained much material relating to the former surveys from Shumard and Swallow, with apparently the intention of editing their notes and publishing them. So far as known, however, nothing was done, and on March 18 the law governing the bureau was amended. Dr. J. G. Norwood, who with Dr. C. M. Litton had been one of Hager's assistants, remained temporarily in charge of the affairs of the survey from September 1, 1871, until November of the same year, when R. Pumpelly was placed at the head of the organization. Norwood, during his brief period of authority, was assisted by G. C. Broadhead and C. M. Litton.

Pumpelly's Survey of Missouri, 1871.

Under the management of Pumpelly there were issued in 1873 two volumes of reports, the first a royal octavo of 325 pages which contained all of the "previously unpublished material" that had been transmitted to him by earlier workers on the geological survey of Missouri. This comprised the reports of Broadhead, Meek, and Shumard, and contained eight geological maps of counties and numerous sections.

In this same year there was published, also under the supervision of Pumpelly, a preliminary report on the iron ores and coal fields, forming a volume of 440 pages and 190 illustrations in the text, with a large folio atlas of 15 sheets. Pumpelly was assisted in the preparation of this work by G. C. Broadhead, W. B. Potter, Adolph Schmidt, and C. J. Norwood as geologists; and Regis Chauvenet, chemist. Other assistance was rendered by W. E. Guy, J. R. Gage, and Jackson Leonard.

In the report on the iron and coal, Pumpelly seems directly responsible only for the ideas advanced in the first 28 pages. It is worthy of note that even at this late date Pumpelly seems to have regarded the porphyries of Pilot Knob and adjacent regions as sedimentary rocks. He wrote:

> The porphyries are older than the Silurian and belong to the Archean (Azoic) formation of which they may be the youngest member in Missouri. * * * They are stratified on an immense scale, but owing to the rarity of interstratified beds of other rocks the unraveling of the internal structure of the district is a difficult problem.

The porphyry hills, like Pilot Knob and others, he regarded as Azoic rocks, the exposed portions of the skeleton of the eastern part of the Ozark range, rising from 300 to 1,800 feet above the level of the surrounding country. "They form an archipelago of islands in the Lower Silurian strata, which surround them as a whole and separate them from each other." The rocks overlying these he regarded as belonging to the oldest members of the Silurian, and thought that they might be the deep-seated equivalents of the Potsdam sandstone, or even older.

The region of these porphyries, as well as the Ozark range in general throughout Missouri, had, in his opinion, apparently been above the level of the sea from a very early period (perhaps since the Carboniferous and Silurian) to the present time.

He recognized the fact that the surface ore at Iron Mountain was a residuary product resulting from the disintegration and gradual removal of the siliceous rocks in which the iron ore was originally embedded, the instance offering, as he stated, an extreme case where decomposition of the porphyry in mass facilitated the separation of the ore from the rock and the mechanical removal of the latter.

Concerning the ultimate origin of the iron, Pumpelly was silent. Regarding the origin of the manganese ore as at Cuthbertsons Hill, in township 33, he wrote:

It would seem that we have in these occurrences instances of replacement, but it is difficult to imagine a direct substitution of manganese oxides for the decomposition products of a porphyry, and all the more so in this case from the fact that the analysis shows the remaining porphyry, which is intimately associated with the ore, to have its normal constitution.

He further described what he called a metaphoric limestone at Huffs, near Ackhursts, as—

nearly wholly changed into a porphyry or jasper rock, it having here a schistoid structure in which the alternate laminæ are impure, compact carbonate of lime. * * * Here is a member of the porphyry series which was originally, unquestionably, a limestone, but in which the original physical and chemical characteristics have almost wholly disappeared. It should not seem impossible that the manganiferous rocks which have been described may have had a similar origin, and that the manganese and iron oxides owe their present existence to a former replacement of the lime-carbonate by iron and manganese salts. The porphyry which now surrounds these ores may be due to a previous, contemporaneous, or subsequent replacement of the lime-carbonate by silica and silicates.

A "may be" to which few would assent at this date.

A general discussion of the iron ores and their distribution was comprised in the report of Mr. Chauvenet, which occupied 192 pages of the entire volume. According to this writer the ores of Iron Mountain are due to deposition from solution in water which filtered into fissures. Adolph Schmidt regarded these same ores as replacement products and attempted to explain their formation as follows: When a solution of sulphate or chloride of iron containing also carbonic acid remains for any length of time in contact with a porphyry the latter will become decomposed, the alkalies being set free in the form of carbonates. The carbonates, reacting on the iron-bearing solutions, will precipitate the iron as oxides, which will fill the pores in the porphyry made by the removal of the alkalies. The silica set free in the process would be to some extent removed, but most of it would remain. The silicate of alumina would be decomposed by bicarbonate of iron in solution and removed in the form of a soluble bisilicate, as explained by Bischoff. It is needless to say that these views were not generally accepted.

Next to Owen's Key to the Geology of the Globe, I know of no more extraordinary publication relating to American geology than that of the artist George Catlin, entitled The Lifted and Subsided Rocks of America, with their Influences on the Oceanic, Atmospheric, and Land Currents, which was published in London in 1870.

Catlin's Views on Geology, 1870.

One can forgive any amount of ignorance relating to the subject of geology in a man of Catlin's profession, but it is not so easy to forgive him for putting before an indiscriminating public opinions which are founded on wholly insufficient, and in many cases visionary, data.

Catlin had traveled extensively throughout the western portions of North America and naturally had been attracted by the enormous amount of erosion and uplift manifest in a treeless area. That his thoughts should have been turned in this direction is not at all strange, but his conclusions are such as can be accounted for only on the grounds that he had received absolutely no training, had not learned how to observe, nor how to reason from that which he saw.

The most striking features of the work are those relating to the cause of the Gulf Stream and the origin of the Gulf of Mexico. He conceived that from both North and South America there issued two large subterranean streams of water, one flowing from the north to the south under the main axis of the Rocky Mountains, and the other in an opposite direction along the main axis of the Andes. These becoming heated through proximity to the volcanic fires in the region of the equator, finally issued, giving the necessary volume and temperature to account for the Gulf Stream.

The origin of the gulf itself he imagined to be due to an undermining of the crust of the earth and its subsequent falling in, through the solvent action of the heated water, and he figures the continent both before and after the catastrophe.[a]

[a] Catlin's book was noticed in the American Journal of Science, L, 1870, and dismissed with the following curt remark: "The writer of this work, well known for his travels among the American Indians, here treats of mountain drainage, upheavals, metamorphism, making of mountain chains, sinking of mountains, and of the Indian races of America. He presents his geological views and criticisms with great positiveness, which is consistent with the fact of his limited knowledge of the subject."

In 1871, Dr. F. V. Hopkins, professor of geology, chemistry, and mineralogy in the State University of Louisiana, issued a report on the geology of the State, relating particularly to the post-Tertiary deposits, and containing also a colored geological map. These deposits he divided into (1) Drift, (2) Port Hudson (so-called by Hilgard), (3) the Loess, and (4) the Yellow Loam, the last three being included also under the general name of Bluff Formation.

F. V. Hopkins' Geology of Louisiana, 1871.

Hopkins held (and Dana approved) that the Port Hudson and overlying beds were deposited when the land was at a lower level than now, and that the loess was the accumulation over an old flood plain of the Mississippi, as suggested by Lyell. The drift itself, however, he conceived to be due to the agency of icebergs in a sea at least 1,159 feet deep in the Ohio Valley. To this last view Dana, of course, objected.

In 1872 the subject of the formation of the great features of the earth's surface, including, of course, the formation of mountains, was brought up once more by Joseph Le Conte, then professor of geology and natural history in the University of California. In a series of articles in the American Journal of Science for this year he reviewed the ideas of Humboldt and others; discussed the probable condition of the earth's interior, whether fluidal or otherwise; and announced himself as convinced that the whole theory of igneous agencies, which formed the foundation of theoretic geology, should be reconstructed on the basis of a solid earth.

Le Conte's Ideas on Mountain Making, 1872.

On the assumption that such an earth would be not homogeneous, but that some areas would possess greater conductivity than others and would, therefore, cool and contract more rapidly in a radial direction, he affirmed that the present sea bottoms represented the areas of most, and the continents and mountain ranges those of less, rapid cooling and contraction. This he felt was borne out by the researches of physicists who had shown that the continental masses were less dense than suboceanic matter.

To him the cooling earth might be regarded as composed of concentric isothermal shells, each cooling by conduction. The exterior being the first to cool and solidify, would, through the shrinking away of the still cooling interior, become subjected to powerful horizontal pressure or thrust, which as time went on would find relief in the direction of least resistance (i. e., upward) and along lines of weakness. It was, however, his idea that this yielding was not by upbending into an arch, but by a mashing or crushing together horizontally like dough or plastic clay, with more or less folding of the strata and an upswelling or thickening of the whole squeezed mass.

He showed that, were a mass of sediments 10,000 feet in thickness subjected to horizontal pressure and crushing sufficient to develop well-marked cleavage structure, a breadth of 2½ miles would be crushed into 1 mile, and 10,000 feet thickness would be swelled to 25,000, making an actual elevation of the surface of 15,000 feet. He, therefore, felt justified in asserting that the phenomena of plication and of slaty cleavage demonstrated a crushing together horizontally and an upswelling of the whole mass of sediments, the upswelling produced by this cause alone being sufficient to account for the elevation of the greatest mountain chains.

Hall's theory, previously noted (p. 499), he regarded as wholly failing to explain the actual process by which the chains had been formed; and, taking into account the breadth of the Appalachians (at least 100 miles), he showed that the gentleness of the supposed convex curve of Hall would not produce the amount of crushing necessary for the formation of the immense plication.

Moreover, he pointed out the fact that sedimentation and subsidence were going on together, and, therefore, that the upper surface was probably never convex at all, but nearly or quite horizontal all the time. Subsidence under such conditions might produce horizontal tension or stretching of the lower strata, but could not produce the crushing and plication of the upper.

To Whitney's idea that plication was the result of the subsidence of a mountain axis he likewise took exception, and contended that chains and ranges were, beyond question, produced by horizontal thrust, crushing together the whole rock mass and swelling it up vertically, this thrust being the necessary result of secular contraction of the interior of the earth. In other words, "mountain chains are formed by the mashing together and upswelling of sea bottoms where immense thicknesses of sediments have accumulated, and as the greatest accumulations usually take place off the shores of continents mountains are usually formed by the uppressing of marginal sea bottoms." The submarine ridges and hollows shown by the soundings of the Coast Survey to exist along the course of the Gulf stream, extending from the point of Florida to the coast of New England, he felt might be true submarine mountain ranges now in course of formation by the processes already described.

Referring to the subject of metamorphism of rocks, as shown in mountain chains, he argued as follows: Supposing sediments accumulating along the shores of a continent. The first effect is lithification, and, therefore, increasing density, causing contraction and subsidence *pari passu* with the deposit. Next, if the sedimentation continue, aqueo-igneous softening or even melting would follow, not only of the lower portions of the sediments themselves, but of the underlying strata upon which they were deposited. Finally, this softening would be sufficient to cause a yielding to horizontal pressure along the line, and a consequent upswelling of the line into a chain. Even the granitic axes of mountain ranges might, he thought, in most cases be but the lowermost, and, therefore, most highly metamorphosed portions of the squeezed mass, exposed by erosion.

He agreed with Richthofen and Whitney that the great masses of lava, often constituting the chief bulk of mountain chains, had not come from craters but from fissure eruptions, and that volcanoes are themselves only secondary phenomena, produced by the access of meteoric water to the still hot interior portions. He did not, however, agree with them in assuming that this fluidal mass was a part of a universally incandescent liquid interior, but rather a submountain reservoir locally formed. He felt that this theory, while not dependent upon, was powerfully supported by, the views of Rose, Bischoff, and others as to the metamorphic origin of granite and other igneous rocks, a view which regarded the surface materials as having passed by perpetual cycles through all the stages of rocks and soils—igneous rocks disintegrated to soils carried away and deposited as sediments; consolidated into stratified rocks; metamorphosed into gneiss, granite, or even lavas; to be again, after eruption, reconverted into soils, and recommence the same eternal round.

In furtherance of these same views, Le Conte in 1876 gave, in the American Journal of Science, the results of observations made in the Coast Range Mountains of California along the line of the Central Pacific Railroad. He found the largely unaltered rocks here thrown into a series of anticlines and synclines with angles of dip varying from 65° to 70°. From this he estimated that the original matter as deposited on a sea bottom must, in the building of the range, have been crushed from a breadth or width of 15 to 18 miles into 6 miles, with a corresponding upswelling of the whole mass. In 1878 Le Conte had another paper in the same journal on the same subject, in which he argued that mountain ranges are always formed by horizontal pressure, and that this pressure on a large scale could be produced only by the interior contraction of the earth. To overcome the objections raised by some to this theory to the effect that interior contraction could not concentrate its manifest results along certain lines without such a slipping and shearing as is impossible in a solid earth, he conceived the presence of a solid nucleus and a solid crust separated by a zone of fused or semifused matter. To an objection that contraction based upon shrinkage alone was inadequate to produce the evident results, he argued that there might be other causes, such as loss of water in form of vapor by volcanic action, and still others concerning which as yet nothing was known. His theory of origin, as he here summed it up, consisted of three stages: (1) A stage of preparation by sedimentation; (2) a stage of yielding by horizontal pressure; and (3) a stage of erosion or mountain decay.

Sketch of Le Conte.

Le Conte was born in Liberty County, Georgia, February 26, 1823, and grew to manhood under influences of ease and enjoyment such as have fallen to the lot of few American geologists. Educated as a physician, he early gave up practice and in 1850 removed to Cambridge, in Massachusetts, to become a student of Agassiz. In less than two years he, however, returned to Georgia, where he became professor of natural science at Oglethorpe University. His stay here was brief. In December, 1852, he became attached to the University of Georgia, at Athens, and, in 1856, professor of chemistry and geology in South Carolina College, at Columbia. Here he remained, enduring the vicissitudes of the civil war, but abandoned his beloved South in 1869 (at a period when men of his type were most needed) to become professor of geology, zoology, and botany in the University of California, at Berkeley. Here he remained until his death, in 1902.

FIG. 88.—Joseph Le Conte.

Hilgard's Work at Petite Anse, Louisiana, 1872.

In 1866 E. W. Hilgard, at the suggestion of Professor Henry, of the Smithsonian Institution, visited the salt deposits of Petite Islands and published the results of his observations in the Smithsonian Contributions to Knowledge in 1872, under the title On the Geology of Lower Louisiana and the Salt Deposits of Petite Anse.

As was to be expected, Hilgard differed completely with Thomassy, whose work has been noted, and who, it will be remembered, regarded the island as of volcanic origin. On the contrary, the island, and others of the group, were regarded as Cretaceous outliers, with cappings of drift and other alluvial matter, the salt beds themselves being of Cretaceous age.

Both Hilgard and Thomassy believed the sand and shingle detritus covering a large portion of the States bordering on the lower Mississippi was due to a great flood, which might have resulted from the rapid melting of the northern glaciers. Referring to the belief expressed by some of the western geologists to the effect that the main body of the drift was due to floating icebergs on an inland sea, Hilgard conceived its northern limits to have been fixed by the ice barriers. Toward the east, southeast, and southwest it would be defined by the Allegheny, Cumberland, and Ozark ranges, the main outlet lying, doubtless, in the axis of the Mississippi Valley, the gap between the

Ozark and Cumberland highlands not having been eroded to its present level.

A sudden break in the lower portion of the barriers would, he argued, produce the phenomena as now observed, namely, the action of violent currents plowing up and redepositing the material of the more ancient formations, carrying down in the main channel rocks of high northern derivation, restratifying and otherwise modifying toward the end a good portion of the iceberg drift and, as the current diminished, covering over the coarse material with the Orange sand.

W. C. Kerr on Effects of Earth's Rotation, 1873.

In 1873 W. C. Kerr, State geologist of North Carolina, published in the Proceedings of the American Philosophical Society a brief but suggestive paper on the possible influence of the earth's rotation on the deflection of rivers. He called attention to a fact so obvious as to have been evident to the common people of that State, that in both the Carolinas the eastward flowing rivers always presented high banks and bluffs on the south side and low plains and swamps on the north; also to the fact, owing to these topographical conditions, that the large towns and main roads were always on the south side also.

In seeking for a cause for this Kerr rejected the slow subsidence theory of Tuomey, and suggested that it was due rather to the rotation of the earth, coacting with the force of the river currents, and called in to sustain his opinions the law of motions as developed by Prof. W. Ferrel:

> In whatever direction a body moves on the surface of the earth there is a force arising from the earth's rotation which deflects it to the right in the northern, but to the left in the southern hemisphere.

Whether or not the application of this principle was original with Kerr, it is of course impossible to say. This, however, seems to have been its first application in America, though von Baer had suggested as early as 1860 like results in the case of north and south flowing rivers, as the Irtisch and the Volga of Russia.

Kerr's Work in North Carolina, 1870.

Kerr's final report on the geology of North Carolina, although presented in 1870, was not printed until 1875, owing to the parsimonious action of the State legislature, the public printer being allowed finally to set it up only under condition that the work be done in intervals of other work on the laws, documents, supreme court reports, etc.

The report was accompanied by a colored geological map and three colored sections. The classification of the rocks adopted was as shown on next page.

PROGRESSIVE THEORETICAL VIEW.

The following scheme exhibits the progress of theoretical notions which have obtained at different times with regard to the classification of the formations—the age and horizon of the rocks in the State:

Mitchell, 1842.	Emmons, 1856.		Present, 1875.	
		Post-Pliocene	Quaternary.	
Tertiary	Tertiary	Pliocene	Miocene.	Tertiary.
		Miocene		
		Eocene [a]	Eocene.	
Secondary		Cretaceous	Cretaceous.	
		Triassic	Triassic.	
		Permian		
Transition	Taconic		Silurian? Huronian.	
Primitive		Gneiss	Laurentian.	
		Granite		
		Syenite		

[a] Also partly Quaternary and partly Cretaceous.

This report gave a very fair summary of the knowledge of the geology of North Carolina up to date. The thin gravels overlying the eroded surfaces of the Eocene, Miocene, and Cretaceous in the eastern part of the State were regarded as of glacial origin, the underlying rock being planed down by the currents and drifting ice which brought the bowlders from the Archean hills of Chatham. This idea is not, however, generally accepted, North Carolina being now universally recognized as far south of the glacial limit.

The gold-bearing gravels were looked upon as beds of till which had crept down the declivities of the hills and mountains, as glaciers descend Alpine valleys by successive freezing and thawing of the whole water-saturated mass, both gravitation and the expansion of freezing contributing to the downward movement. This is evidently the same idea as that later advanced by I. C. Russell in his description of the débris streams of Alaska.

Appendices attached contained a list and descriptions of the new genera and species of fossil shells, by T. A. Conrad, and the minerals of the State, by F. A. Genth. A chapter on corundum and its associated rocks, by C. D. Smith, is mainly of interest from the fact that Smith regarded the chrysolitic rocks as of igneous origin, a conclusion which for sometime was disputed, but to which later workers have returned.

Kerr was of Scotch-Irish descent, though born in North Carolina. His parents dying while he was quite young, he was adopted by a Rev. Dr. Caruthers, a Presbyterian minister, under whose instruction he was fitted for the State University at Chapel Hill, where he graduated in 1850 with highest honors. After graduation he taught school for a while at Williamstown in his native State, until elected to a professorship in Marshall University, Texas. This position he resigned in 1852 to accept an appointment as computer in the Nautical Almanac Office, then located at Cambridge, Massachusetts. While here he entered the Lawrence Scientific School and studied under Agassiz, Gray, and the chemist Horsford.

Sketch of Kerr.

In 1857 he accepted a professorship at Davidson College in North Carolina, where he remained until 1865, though his active work ceased in 1862, owing to a falling off in income and students, incident to the civil war. From the latter part of 1862 to early in 1864 he was chemist and superintendent of the Mecklenburg Salt Works, near Charleston, South Carolina, but after the destruction of the works, returned to North Carolina, where he became nominally State geologist in 1864, though active work, owing to the confusion and disorganization of war, did not begin until 1866.

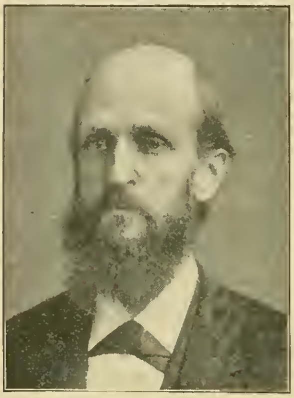

Fig. 89.—Washington Caruthers Kerr.

It is safe to say that few men ever entered upon the work of a geological survey under more unfavorable auspices. He himself had had no extended experience, nor was he a trained specialist. Little money was available, the industries of the State paralyzed, and her social conditions disorganized, if not demoralized. The State had never a more genuine and sagaciously public-spirited citizen than he, but the times were evil, and for several years Professor Kerr shared the fate of all public officials who were endeavoring to adjust, to reconcile, and to go forward. His motives were misrepresented, his character assailed, his abilities questioned, his work maligned. Yet in the face of all this, without good maps and with few roads, a great work was accomplished.

During one of the first years of the survey he traveled, mainly on horseback, 1,700 miles over mountainous country, with and without roads, and during the season of 1866 and 1867 not less than 4,000 miles. Work thus performed was from necessity largely in the nature of reconnaissance. The subjects of drainage and topography received a large share of attention, and indeed a large part of his work was along physiographic lines, though by no means limited thereto. Agricultural and mineral resources were investigated and, so far as possible with the limited means at his command, advertised. His papers which attracted the most widespread attention were doubtless those relating to the action of frost on superficial materials and the unequal erosion of the banks of a stream, due to the earth's rotation.

Kerr was a man of slight physique, and for the last ten or fifteen years of his life suffered from catarrh of the digestive organs. The funds available were too small to enable him to employ permanent assistants, either in the field or as clerk or amanuensis. Under these circumstances the amount of work accomplished was certainly remarkable.

He was an exceedingly liberal man—a man of generous temper and of large views. * * * He was deeply religious and always prominent, although in an unobtrusive way, in matters pertaining to the church. As a Christian gentleman, those who have known him best have admired him most. His heart was warm and generous, his mind clear, active, and progressive, his conscience keen and inflexible. He was honest in every sense of the word. There was nothing of policy in his thought or action; on the contrary, he was frank and outspoken, at times even to a fault. (Holmes.)

Smith's Work in Alabama, 1873.

In 1873 the legislature of Alabama passed an act reviving the survey, which had been discontinued after the death of Professor Tuomey, in 1857, and named Prof. Eugene A. Smith, of the University of Alabama, State geologist. This office Professor Smith has continued to hold down to the present time. Up to and including 1880 he had made five reports. These were given up mainly to a discussion of the geographic distribution of the various formations comprised within the State limits, with extensive notes regarding the economic possibilities of coal, iron, and other minerals of less importance.

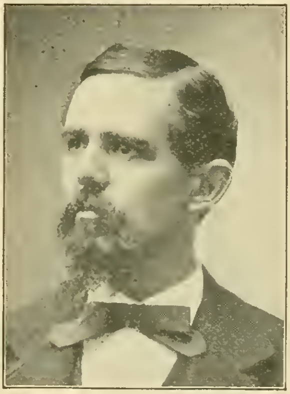

Fig. 90.—Eugene Allen Smith.

In his report for 1875-76 he treated of the geology of Jones Valley and the Coosa Valley region and announced the practical identity of the formations there found with those described by Professor Safford in Tennessee, recognizing the Ocoee, Chilhowee, Knox sandstone, shale and dolomite, and Lower and Upper Carboniferous. In those of 1877, 1878, and 1879 special reference was made to the Warrior coal fields and their probable value. Several colored county maps were given, but no geological map of the entire State.

Second Geological Survey of Kentucky, 1873-1891.

In the spring of 1873 there was organized a second geological survey of Kentucky, with N. S. Shaler, then professor of paleontology at Harvard, chief geologist and director, and A. R. Crandall, P. N. Moore, C. J. Norwood, and J. R. Proctor, assistants. Dr. Robert Peter served as chemist. The organization continued as above until 1880, when J. R. Proctor succeeded to the directorship through the resignation and recommendation of Professor Shaler, the survey coming finally to a close in 1891.

Up to 1880 five reports of progress were issued, dealing mainly with economic problems.

The plateau country drained by the Colorado River offers facilities for the study of geological problems such as are, perhaps, equaled nowhere else in the world. This is especially true with reference to problems relating to stratigraphic succession, of uplift with a minimum amount of contortion of the beds, and of erosion. The plateau nature of the country was recognized by Newberry while with the Ives expedition in 1860, and by Blake in connection with the Pacific Railroad surveys in 1856. It remained, however, for Powell, Gilbert, and Dutton to first bring out the salient features of the geology of the region and to work out the problems in a way that, to quote the words of Emmons[a], has formed the starting point of modern physical geography.

Powell's Exploration of the Grand Canyon, 1869-1874.

In the summer of 1869, J. W. Powell, a retired officer of the Federal Army, made a boat trip down the Colorado, starting from Green River City on the Union Pacific Railroad May 24, and emerging from the mouth of the Black Canyon, nearly 900 miles below, on August 30 following—a journey that, to quote Emmons again, "is unequaled in the annals of geographical exploration for the courage and daring displayed in its execution."

FIG. 91.—John Wesley Powell.

In his reports on these explorations,[b] which were made and published under direction of the Smithsonian Institution, Powell called attention to the fact that the canyons are gorges of corrosion and due to the action of the river upon the rocks, which were undergoing a gradual elevation. As he expressed it, the river preserved its level, but the mountains were lifted up; as the saw revolves on a fixed pivot while the log through which it cuts is moved along. The river was the saw which cut the mountain in two. This is essentially the idea advanced by Hayden in 1872 in his report on the geology of Montana.

In this report Powell first made use of the expressions of *antecedent* and *consequent* valleys, meaning in the first instance that the drainage was established prior or antecedent to the corrugation of the beds by faulting and folding; and in the second case, that the valleys have directions which are dependent upon the corrugations. Valleys which were formed by streams, the present courses of which were deter-

[a] Presidential address, Geological Society of Washington, 1896.

[b] Letter of transmittal dated June 16, 1874; publication in 1875.

mined by conditions not found in the rocks through which the channels are now carved, but which were in existence when the district last appeared above sea level, he called *superimposed* valleys.

In this same report, too, Powell made use for the first time of the term *base level of erosion*, which he defined as—

an imaginary surface inclining slightly in all its parts toward the end of the principal stream draining the area through which the level is supposed to extend, or having the inclination of its parts varied in direction as determined by tributary streams.

He pointed out, further, that the region of the Grand Canyon was after all a region of lesser rather than greater erosion; that had the country been favored with a rainfall equal to that of the Appalachian country, the entire area might have been reduced to a base level which would be the level of the sea, though the evidence of such erosion might be almost wholly obliterated.

J. P. Lesley on Iron Ores and Denudation, 1874.

J. P. Lesley, writing in 1874 on the iron ores of Spruce Creek, Warriors Mark Run, and Half Moon River, in Huntingdon and Center counties, Pennsylvania, took the ground that they were residual deposits from the decomposition of ferriferous Lower Silurian beds, which were at one time buried beneath more than 16,000 feet of Upper Silurian, Devonian, and Carboniferous rocks, and had been subsequently exposed through decomposition and erosion.

At the end of the coal era the Middle States rose from the waves. * * * The edges of the Bellefonte fault stood as a mountain range as high as the Alps, and the backs of some of the great anticlinals of Pennsylvania must have formed plateaus then as high as Tibet and Bootan are now.

Erosion commenced and has continued through the Permian, Jurassic, Cretaceous, and Tertiary ages to the present day, and still goes on. The high plateau was gradually worn down to the present surface. Mountains once 30,000 or 40,000 feet high are now but 2,000 or 3,000 above sea level.

Such extreme views as to the possible height of mountain ranges are equaled among modern geologists only by those of Clarence King (p. 612).

Winchell's Work in the Black Hills, 1874.

In 1874 N. H. Winchell accompanied, as geologist, the party headed by Capt. W. Ludlow to the Black Hills of Dakota. His report, appearing in 1875, occupied pages 21 to 66 of the quarto volume issued, and was accompanied by a geological map. Winchell recognized the occurrence of Cretaceous, Jurassic, Triassic, Carboniferous, and Silurian (Potsdam) rocks, overlying schists and slates, into and through which granite had been intruded. He agreed in the main with Hayden's observations, as given in his Second Annual Report (1868), though he failed to find evidence of the unbroken conformability of the fossiliferous formations. On the contrary, he mentioned the Red Beds as lying unconformably on the Carboniferous limestone.

George Bird Grinnell accompanied the expedition in the capacity of paleontologist, though the new species of invertebrate fossils found (*Obolus pectenoides*, *Terebratula helena*, and *Lingulepis primæformis*) were described and figured by R. P. Whitfield.

Work of Jenny and Newton in the Black Hills, 1875.

The presence of numerous bands of prospectors on the Indian reservations of the Black Hills, led there by the reported finding of gold by Custer's and other expeditions, caused the National Government, in 1875, to send "trusty persons" to examine the region and report to the Secretary of the Interior, in order that a proper basis might be secured for future negotiations with the Indians. The locality being then comprised in the Sioux Indian reservation, immediate direction of affairs was put in the hands of the Indian Bureau. Under this authorization W. P. Jenny was appointed to undertake the work, with Henry Newton as assistant. The party entered the region on the 3d of June, some 400 strong, a large military guard being esteemed necessary on account of the manifest discontent of the Indians, and returned to Fort Laramie on October 14, after an absence of four months and twenty days. A preliminary report on the mineral resources of the Hills, accompanied by a map by V. T. McGillycuddy, the topographer, was submitted by Mr. Jenny and published in the report of the Commissioner of Indian Affairs for 1875. The complete report on the mineral resources, climate, etc., with a preliminary map, was published in the form of an octavo pamphlet of 71 pages in 1876, and the final Report on the Geology and Resources of the Black Hills of Dakota, in form of a quarto volume of 566 pages, with large folio atlas, in 1880. This included, also, the previous reports on the mineral resources, noted above. Unfortunately, Doctor Newton, to whom was left the general geology of the region, died before his report was fully prepared for the press, the work being ably edited by G. K. Gilbert, and the volume issued as one of the monographs of the Powell survey.

The Black Hills region, it will be remembered, had already been touched upon and fragmentary surveys made by numerous parties, including Dr. John Evans in 1849 and 1853, Thaddeus Culbertson in 1850, Meek and Hayden in 1853, and Hayden, with the military expeditions of Harvey and Warren in 1855 and 1857, and with Captain Raynolds in 1859. Hayden again visited the region under the auspices of the Philadelphia Academy in 1866, and N. H. Winchell with Custer's expedition in 1876, as just noted. Under all these conditions it is difficult to estimate the value of the work of Newton. Much that he stated in his report had already been made known by the authorities mentioned above. On the other hand, much that he might have had in mind to say has never appeared, owing to his untimely death.

The summary of Black Hills history, as given, shows an older Archean consisting of shales and sandstones over which, after an interval of erosion and metamorphism, a newer Archean, consisting mainly of sandstones, was deposited, accompanied by abundant intrusions of granitic rock. Then followed the period in which these rocks were raised to a nearly vertical position, metamorphosed, and deeply eroded, after which the various Potsdam, Carboniferous, Red Bed, Jura, and Cretaceous deposits were conformably laid down. Then followed the uplift and subsequently the unconformable depositions of the White River Tertiaries upon their flanks. The date of the uplift is therefore set as the interval of time between the Cretaceous formation and the beginning of the Miocene Tertiary. (See under Hayden, p. 591.)

Newton showed that the drainage from the Black Hills was consequent—that is, it conformed to the dip of the strata. This he conceived to be caused by the streams having acquired their direction during the uplift of the hills, or while they were being laid bare by the drainage of a lake. In either case the drainage is consequent upon the uplift. With the rivers—the Belle Fourche and the South Fork of the Cheyenne—the case is different, however. These cut across the

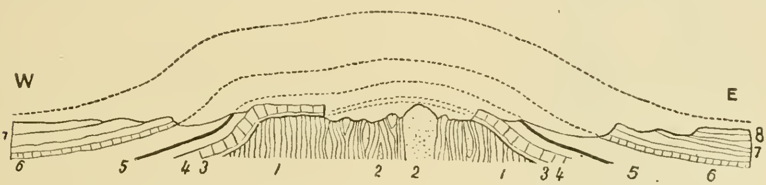

FIG. 92.—Ideal cross-section of the Black Hills. (After Henry Newton.)

The vertical scale is about six times the horizontal; the dotted lines indicate the portion of the uplift removed by erosion; 1, Archean slates and schists; 2, Granite; 3, Potsdam, resting unconformably on 1 and 2; 4, Carboniferous; 5, Red Beds, with included limestone; 6, Jura; 7, Cretaceous; 8, White River Tertiary, resting unconformably on 7.

uplifted strata in a way to show that the drainage is superimposed. If they existed prior to the deposition of the Tertiary sediments they were completely blotted out.

J. H. Caswell described the various metamorphic and eruptive rocks collected by the survey, his paper forming the second on the subject of micropetrography to appear from the Government press, Zirkel's fortieth parallel report (1876) being the first. The report was accompanied by two plates with eight colored figures illustrating microstructure and composition, and is of particular interest as giving the first authoritative account of the occurrence of the rock phonolite in the United States. Caswell, although one of the first in a new and fascinating field, seems to have rested on his laurels, content with the one effort, his name in geologic literature appearing here for the first and only time.

W. P. Jenny, to whom fell the economic work, reported gold occurring (1) in veins of quartz traversing Archean schists and slates; (2) in slate mineralized by waters depositing silica and iron pyrites; (3) in the conglomerate forming the lower layer of the Potsdam sandstone and derived from the Archean rocks; (4) in trachyte and porphyry intruded at the time of the elevation of the hills; (5) "in deposits in the slates and sedimentary rocks produced by the intrusion of the trachyte and porphyry," and (6) "in placer gravels resulting from the decomposition and erosion of the above formations in Tertiary times."

The quartz veins he did not regard as "true fissure veins," but, as they occurred filling fissures between the lamellæ of the schists formed in the process of the folding, were referred to as "interlaminated fissures."

The fossils collected by this expedition were worked up by Whitfield while at Albany in 1876.

Lapham's Survey of Wisconsin, 1873.

Under act approved March 18, 1873, a geological survey of Wisconsin was authorized, and I. A. Lapham appointed State geologist by the then acting governor, C. C. Washburn. Owing to an apparent oversight on the part of Governor Washburn, Professor Lapham's name was, however, not sent to the senate for approval, and an opportunity thereby offered for Governor Washburn's successor, W. R. Taylor, to supersede him by Dr. O. W. Wight. So far as shown by public records, the transaction was purely political and not at all creditable to Governor Taylor.

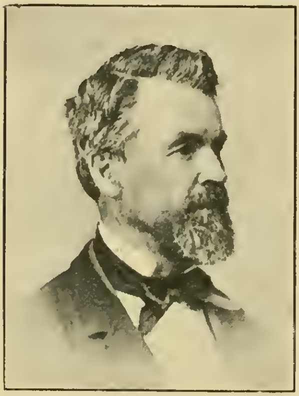

FIG. 93.—Increase Allen Lapham.

Lapham therefore served but two years, during this time rendering two reports. These were not published independently, but subsequently formed the first 65 pages of the second volume of the reports of State geologist, T. C. Chamberlin. He was assisted by R. D. Irving, T. C. Chamberlin, and Moses Strong. The two reports referred to were naturally of a preliminary nature, designed to form the basis for future work. Lapham, perhaps even more than others of his time, was an all-round naturalist—a type not possible in this day and generation. Beginning life as a stonecutter and afterwards a civil engineer, he yet found time to study and observe in nearly all branches of the sciences, and this, too, with remarkable accuracy. His first paper of a geological nature is said to have been prepared when he was but sixteen years of age, and was published in the American Journal of Science for 1828. This gave an account of the geology in the vicinity of the Louisville and Shippingport Canal, and was illustrated by a map and geological sections of a nature very creditable to a youth of his years.

His bibliography includes upward of fifty titles, embracing, besides geology, articles on climatology, archæology, botany, and cartography. He is represented as a modest, patient, and industrious man, living more for the service of others than for his own aggrandizement. He died of heart trouble while alone on a lake near Oconomowoc, Wisconsin.

Lapham was succeeded, as above noted, by O. W. Wight, who served but one year (1875). His one report of progress was not published at the time, but was likewise included by Chamberlin in the second volume of the final reports, bearing date of 1877. It contained matter of little other than historical interest.

In February, 1876, Prof. T. C. Chamberlin was placed in charge of the State survey. The organization continued in existence until 1879, the final reports appearing in the form of four royal octavo volumes, dated, respectively, Vol. I, 1883; Vol. II, 1877; Vol. III, 1880, and Vol. IV, 1882, comprising altogether 3,035 pages.

Chamberlin's Survey of Wisconsin, 1876.

The principal assistants on the survey were R. D. Irving, F. H. King, Moses Strong, E. T. Sweet, J. D. Whitney, and L. C. Wooster. R. P. Whitfield served as paleontologist. Aside from acting as director of the survey, Chamberlin himself took charge of the geology of eastern Wisconsin, of which he described in considerable detail the hydrology, the soils, and the glacial drift. The so-called Kettle Range he believed to be in part moraines, and the kettle holes to be due mainly to the melting of masses of ice buried in the gravels. He discussed the economical value of the clays and shell marls of the region, and for the first time in America demonstrated the usefulness of the microscope in examinations of detrital rocks. In this connection he noted that a microscopic examination of the sand grains of the Potsdam sandstone was entirely fatal to the view still occasionally advanced to the effect that such were produced by crystallization from solution. He, in his turn, however, failed to recognize the possibility of the crystalline form of some of the granules being due to secondary enlargement (see pp. 469 and 553).

Fig. 94.—Thomas Crowder Chamberlin.

The oolitic iron ore lying between the Cincinnati shales and the Niagara limestone was thought to be undoubtedly a marine deposit laid down in detached basins. It was shown, further, that the three well-marked classes of limestone occurring in the southeastern counties of Wisconsin graded into each other and were doubtless formed contemporaneously, the residual mounds or ridges being ancient coral reefs, while the granular sand rock was formed from calcareous sands derived by wave action from the reef, the compact strata being deeper quiet-water deposits of the same material.

Chamberlin also investigated the ore deposits of the southeastern part of the State, and discussed thoroughly the problems involved in the origin of the ores, disagreeing in many minor points with both Doctors Owen and Whitney. The crevices in which the ores occur he believed to have originated primarily in the folding of the rocks by lateral pressure. He pointed out that the ore beds occur mainly in basin-like depressions and argued that the ore material, originally in solution in sea water, was deposited contemporaneously with the limestone through the action of sulphureted vapors given off by the decomposition of organic matter, and that, after the elevation of the beds above sea level, percolating meteoric waters oxidized and dissolved the ore once more and carried it into the fissures above noted, where it was the second time precipitated as sulphides. Fourteen-hundredths of 1 per cent of ore material disseminated throughout 100 feet in depth of the ore-bearing limestone would, he pointed out, be sufficient to have formed all the deposits as they now exist. He did not agree with Whitney in assuming that the oceanic waters of early geologic periods were richer in metallic salts than those of later data, instancing in support of his argument the fact that the ore-bearing beds were in many cases really poorer in organic matter than those which were nonmetalliferous and more ancient. This criticism did not, however, affect the general principle as laid down by Whitney. With his predecessors he doubted the probability of the existence of workable deposits of ore in the Lower Magnesian limestone.

Volume I of the reports of this survey was designed as a general treatise on the geology of the State, suited to the wants of explorers, miners, landowners, and manufacturers. In this Chamberlin stated his belief that the original source of the Keweenawan copper ore was the igneous rocks, from whence it has been concentrated through the agency of permeating atmospheric waters. To quote his own words, he believed—

> First, that the metals, copper and silver, were primitively constituents of the rocks that were melted to produce the lavas which formed the trappean sheets of the formation; second, that they were brought up and spread out, commingled with the molten rock material; third, that they were chemically extracted thence by percolating waters and concentrated in the porous belts or fissures of the formation, giving rise to the exceptionally rich deposits for which the formation is famous; and fourth, that the surface disintegration of portions exposed in the latter part of the period yielded metallic ingredients to the adjacent sea, from whence they were extracted by organic agencies, giving rise to impregnated sediments, which, in turn, through subsequent concentrations, gave rise to other copper and silver deposits, among which are to be reckoned the later metallic horizons of the Lake Superior region and possibly elsewhere.

Naturally, the subject of the drift was treated in considerable detail. The Glacial period was divided into the Terrace or Fluviatile epoch, Champlain or Lacustrine epoch, the Second Glacial epoch, inter-Glacial epoch, and first Glacial epoch. This formal announcement of the fact that there had been two distinct periods of glaciation was here made for the first time, although as noted on page 463, Prof. Edward Hitchcock had suggested its possibility as early as 1856. The law of flowage Chamberlin regarded as essentially similar to that of viscous fluids, in accordance with the observations of Agassiz, Forbes, Tyndall, and others. A later study of Greenland glaciers has caused him to change his views on this point.

R. D. Irving, 1873-1879.

Irving, as one of Chamberlin's assistants, dwelt with great detail on the lithological character of the rocks in the regions surveyed by him, and his reports are notable for the beauty of the colored plates of thin sections, which were by far the best that had been prepared and published by an American up to that date. He was assisted in this part of the work by C. R. Van Hise. He also described in some detail the glacial drift, and was the first to announce that the Kettle Range of central Wisconsin was a continuous terminal moraine.

FIG. 95.—Roland Duer Irving.

Third Edition of Dawson's Acadian Geology, 1878.

In the third edition of his work on Acadian Geology, which appeared in 1878, Dawson returned once more to a vigorous discussion of the problems of the ice age, and to register again his opposition to the views generally held by American geologists. Many of the arguments used closely resembled those of his former papers and may be reviewed here for the last time. He regarded the phenomena of the bowlder clay and drift in eastern America as due to the action of local glaciers, drift ice, and the agency of cold northern currents. Against the theory of an universal glacier he again argued on the ground that such suppositions were not warranted by the facts. "The temperate regions of North America could not be covered with a permanent mantle of ice under existing conditions of solar radiation; for, even if the whole were elevated into a table-land, its breadth would secure a sufficient summer heat to melt away the ice except from high mountain peaks." For the supposition that such immense mountain chains existed and have disappeared, he found no warrant in geology, and for such an "unexampled astronomical cause of refrigeration" as the earth's passing into a colder portion of space, he found no evidence in astronomy. Against Frankland's idea that glaciation was brought about through a higher temperature of the sea along with a lower temperature of the land, he instanced the actual colder condition of the sea, as shown by the fossils of that period. He agreed with Lyell in regarding the theory of the varying eccentricity of the earth as expounded by Croll as insufficient; moreover, it seemed to him physically impossible that a sheet of ice such as that supposed could move over an uneven surface, striating it in directions uniform over vast areas and often different from the present inclination of the surface.

He was further influenced in his opinion by the work of Hopkins, who showed, apparently, that only the sliding motion of glaciers could polish or erode rock surfaces, and the internal changes in their mass—the result of weight—could have little or no effect. Glaciers, moreover, he argued could not have transported the bowlders great distances and lodged them upon the hilltops, and the universal glacier would, moreover, have no gathering ground for its materials. The huge feldspar bowlders from the Laurentide Hills, stranded at Montreal Mountain at a height of 600 feet above the sea and from 50 to 60 miles farther southwest, and which must have come from little, if any, greater elevation and from a direction nearly at right angles to that of the glacial striæ, were against the ice-sheet theory, as were also the large bowlders scattered through the marine stratified clays and sands, and the occurrence of marine fossils in the lower part of the drift, in the true till near Portland and Cape Elizabeth, Maine, and at various points on the St. Lawrence in Canada. In the Post-Pliocene deposits of Canada he found evidence of a gradual elevation from a state of depression which may have amounted to more than 500 feet, while only the bowlder clay represents the previous subdivision, and only striations on the rocks indicate an ice-clad condition of the land. Both plant and animal life indicated to him that the conditions of temperature of the sea were not greatly different from those of to-day.

Referring to the direction of the striæ, he found evidence such as led him to declare without hesitation that their direction is "from the ocean toward the interior against the slope of the St. Lawrence Valley." This, he felt, at once disposed of the glacial theory for the prevailing set of striæ, since he could not suppose a glacier to move from the Atlantic up into the interior. On the other hand, he regarded it as eminently favorable to the idea of ocean drift. A subsidence sufficient to convert the Canadian plains, New York, and New England into a sea would, he thought, cause the Arctic current to pour over the Laurentide rocks on the north side of Lake Superior and Lake Huron, cutting out the softer strata to form their beds, and drifting their materials to the southwest. The lower strata of the current would be diverted through the strait between the Adirondacks and Laurentide Hills, and, flowing over the ridge of hard rocks which connects them at the Thousand Islands, would cut out the long basins of Lake Ontario, heaping up at the same time in the lea of the Laurentian ridge the great mass of bowlder clay which intervenes between Lake Ontario and Georgian Bay. Lake Erie and Lake Michigan were, he argued, cut out by similar currents. At times of obstruction of currents which produced the southwest striations, while the valleys of the Ottawa, Mohawk, Lake Champlain, and the Connecticut were arms of the sea, the currents would set along these arms, producing the northwest and southeast striations.

Local glaciation might prevail in high peaks, but the so-called moraines were to his mind shingle beaches and bars and old coast lines loaded with bowlders and ozars. The fiords on the coast, like the deep lateral valleys of mountains, were evidences of the action of waves and currents rather than those of ice.

The subsidence noted above, which would result in converting the plains of Canada, New York, and New England into seas and cause the Arctic current to flow over the submerged area from northeast to southwest, would produce a current which would move up a slope, and the ice which it bore would, therefore, tend to ground and grind the bottom as it passed into shallow water.[a]

In the first edition (1855) of Acadian Geology the occurrence of the albertite deposits in the Lower Carboniferous rocks of New Brunswick received considerable attention. In the discussions there given relating to their origin, he concludes that the material belongs to the purest variety of bituminous coal, related to the pitch coals or jets. He admitted, however, that it had some claim to be considered a distinct mineral species intermediate between the coals and asphalts. At that time he regarded the deposit as having originated through the deposition of organic matter in fresh water, the deposit having since been very singularly distorted by mechanical pressure.

In the second edition of the work (1868) he, however, modified his expressed opinion, accepting the views of more recent explorers like Hitchcock, Bailey, and Hind, who had described the deposit as a vein

[a] To substantially these views Dawson held to the very last. In his Ice Age in Canada (1893) he is found still combating vigorously the idea that all northern Europe and America were covered by a *mer de glace* moving to the southward and outward to the sea, and which moved not only stones and clay to immense distances, but glaciated and striated the whole surface. The glacial theory of Agassiz and others he described as having grown until, like the imaginary glaciers themselves, it overspread the whole earth. He adopted rather what he called the moderate view of Sir Roderick Murchison and Sir Charles Lyell, to the effect that Pleistocene subsidence and refrigeration produced a state of our continents in which the lower levels, and at certain periods even the tops of the higher hills, were submerged under water filled every season with heavy field ice formed on the surface of the sea, as at present in Smiths Sound, and also with abundant icebergs derived from glaciers descending from unsubmerged mountain districts. The later Pliocene, so far as Canada was concerned, he considered to be a period of continental elevation and probably of temperate climate.

filled with bituminous matter. The source of the bituminous matter he supposed to be the Lower Carboniferous shales. In his own words:

> The deposit of the Albert mine would thus be a vein or fissure constituting an ancient reservoir of petroleum which, by the loss of its more volatile parts and partial oxidation, has been hardened into a coaly substance.

He regarded the Nova Scotia gypsum beds as due to the alteration of beds of limestone by free sulphuric acid poured into the sea by springs or streams issuing from the volcanic rocks. In this connection he gave a highly interesting verbal picture of the condition of affairs, as he imagined them to exist, at what is now the Southern Hants and Colchester at the time when the marine limestones and gypsums were produced.

> At this period, then, all the space between the Cobequids and the Rawdon Hills was an open arm of the sea, communicating with the ocean both on the east and west. Along the margin of this sea there were in some places stony beaches, in others low alluvial flats covered with the vegetation characteristic of the Carboniferous period. In other places there were creeks and lagoons swarming with fish. In the bottom, at a moderate distance from the shore, began wide banks of shells and corals, and in the central or deeper parts of the area there were beds of calcareous mud with comparatively few of these living creatures. In the hills around, volcanoes of far greater antiquity than those whose products we considered in a former chapter, were altering and calcining the slaty and quartzose rocks; and from their sides every land-flood poured down streams of red sand and mud, while in many places rills and springs, strongly impregnated with sulphuric acid, were flowing or rising, and entering the sea, decomposed vast quantities of the carbonate of lime accumulated by shells and corals and converted it into snowy gypsum.

The fauna of the seas of the Lower Carboniferous coal formations and Permian periods, both in Europe and America, presented so great similarities that, in a broad view, he felt they were identical. The changes and the subdivisions of this fauna were related not merely to lapse of time but to vicissitudes of physical conditions. It followed that, according to his reasoning, if the peculiar Permian conditions indicated by the rocks came earlier in Nova Scotia than in Europe the character of the fauna might also be changed earlier. In other words, "We have both rocks and shells with Permian aspect in the earlier Carboniferous period." The fact that the marine fauna of the Lower Carboniferous of Nova Scotia more nearly resembled that of Europe than the western States he regarded as indicating that the Atlantic was at that time probably an unobstructed sea basin as now, while the Appalachians already, in part, separated the deep-sea fauna of the Carboniferous seas east and west of them.

Concerning the origin of coal he wrote: "Mineral charcoal results from subaerial decay; the compact coal, from subaqueous putrefaction more or less modified by heat and exposure to air." Further, he regarded mineral charcoal as the woody débris of trees, while the compact coal was produced from the bark of these same trees along with such woody

SIR WILLIAM DAWSON.
Principal of McGill University.

and herbaceous matter as might be embedded or submerged before decay had time to take place.

He referred again to the observations and conclusions made by him in connection with his Joggins work several years previous, to the effect that the layers of clear, shining coal (pitch or cherry coal) are composed of flattened trunks of trees, and that of these usually the bark alone remains, the lamination of the coal being due to the superposition of layers of such flattened trunks alternating with the accumulations of vegetable matter of successive years, and occasionally with fine vegetable muck or mud spread over the surface by rains or by inundations.

The stigmaria found in the clay underlying nearly every bed of coal he felt proved beyond question the accumulation of the coal-forming materials through growth in situ, following in this respect the teaching of Logan. The under or fire clay was thus looked upon as a fossil soil robbed of its alkali and lime through growths of terrestrial vegetation.

The rocks of the Arisaig series, which in 1855 he regarded as Silurian (Devonian ?), in the edition of 1868 he says "must be regarded as representing the middle and upper parts of the Upper Silurian, a position somewhat lower than that assigned to it in the first edition."

The provincial predictions of Dawson in this work are somewhat amusing. Thus, on page 4:

> Further, since by those unchanging laws of geological structure and geographical position which the Creator himself has established, this region must always, notwithstanding any artificial arrangements that man may make, remain distinct from Canada on the one hand and New England on the other, the name Acadia must live; and I venture to predict that it will yet figure honorably in the history of this western world. The resources of the Acadian provinces must necessarily render them more wealthy and populous than any area of the same extent on the Atlantic coast from the Bay of Fundy to the Gulf of Mexico, or in the St. Lawrence Valley from the sea to the head of the Great Lakes. Their maritime and mineral resources constitute them the Great Britain of eastern America, and though merely agricultural capabilities may give some inland and more southern regions a temporary advantage, Acadia will in the end assert its natural preeminence.

Sketch of Dawson.

Dawson was a Nova Scotian by birth, having first seen the light of day at Pictou in 1820. He was educated at Pictou Academy and subsequently at the University of Edinburgh, Scotland, where he came under the influence of Jamieson, Forbes, Balfour, and Alexander Rose. In 1847 he returned to Nova Scotia, and in 1855 assumed the principalship and chair of natural history in McGill University, Montreal, at the head of which institution he remained until 1893, when he was forced by ill health to resign. His first original paper, as has been noted, was on a species of field mouse found in Nova Scotia, and was read before the Wernerian Society of Edinburgh. From so insignificant a beginning he developed into one of the most prolific and voluminous writers. The Geological History of Plants, The Air Breathers of the Coal Period, The Canadian Ice Age, The Dawn of Life, Story of the Earth and Man, Fossil Men and their Modern Representatives, The Meeting Place of Geology and History, and Modern Science in Bible Lands are among the best known of his writings, in addition to the work above reviewed. In educational matters he was always prominent, and the present standing of McGill University is largely due to his industry and ability as an administrator. He is represented by his biographer as a man of quiet geniality, gentle and courtly in manner, but, as may be readily surmised from his record in the Eozoon controversy, decided in opinion and firm in action. Like Alexander Winchell he took a prominent part in overcoming the popular prejudice concerning the supposed antagonism between religion and the sciences, particularly geology. An advanced and liberal thinker, he was, nevertheless, not an evolutionist in the ordinary acceptance of the term. He believed that the introduction of new species of animals and plants had been a continuous process, not necessarily in the sense of deviation of one species from another, but in the higher sense of the continued operation of the cause or causes which introduced life at first. The history of a life, he argued, presents a progress from the lower to the higher, from the simpler to the more complex, and from the more generalized to the more specialized. In this progress new types are introduced and take the place of the older ones, which sink to a relatively subordinate place and become thus degraded. To him paleontology furnished no direct evidence as to the actual transformation of one species into another or as to the actual circumstances of creation of a species; but the drift of its testimony to him showed that species come in *per saltum* rather than by any slow and gradual process.

In 1879 there was published, as already noted (p. 515), part one of Whitney's Auriferous Gravels of the Sierra Nevada of California, and in 1880 part two of the same work, the combined papers comprising a volume of 569 pages, in which the distribution, origin, and characteristics of the auriferous gravels of the Sierras are fully discussed and much information given regarding their method of mining and economic value.

Whitney's Auriferous Gravels, 1879-80.

Discussing the origin of the conglomerates and the prevailing theories regarding their marine origin, he wrote:

> Again, these detrital deposits are not distributed over the flanks of the Sierra in any such way as they would have been if they were the result of the action of the sea. On the contrary, there is every reason to believe that they consist of materials which have been brought down from the mountain heights above and deposited in preexisting valleys; sometimes very narrow accumulations, simply beds of ancient rivers, and at other times in wide lake-like expanses of former water courses.

Subsequent work has apparently fully confirmed Whitney's view.

The time of deposition was put down by him as during the later Pliocene epoch, and not as late as the drift of the Diluvial period.

Many pages were devoted to the vertebrate fossils found in the auriferous gravels, and particularly to the evidences of man, and the Calaveras skull. The question of the contemporaneous deposition of this skull with the gravels has been too frequently discussed by ethnologists to need more than a brief mention here. Suffice for the present to state that Whitney himself seems to have been fully convinced of the genuineness of the find, and regarded it as establishing beyond doubt the existence of Tertiary man in California.

In discussing the source of the gold and its distribution in the gravel Whitney took occasion to express the opinion that, as a whole, the occurrence of metalliferous ores is rather a surface phenomenon than a deep-seated one, and that this is due to the favorable conditions for fissure formation and deposition from solution controlled by temperature and pressure.

The source of the gold he thought to be undoubtedly the quartz veins which traverse the Jurassic slates, a fact to his mind refuting Murchison's theory of the occurrence of gold exclusively in Paleozoic rocks. He found no evidence to support the opinion that the large size of the nuggets in the gravel was due to a gradual growth through chemical precipitation.[a] He regarded such as more or less dentritic and branching masses which have been liberated from the gangue and reduced to pebble form by the pounding they received in the moving gravels.

Whitney's Climatic Changes, 1880-1882.

Whitney's work on the auriferous gravels was followed in 1880 and 1882 by an equally comprehensive work on climatic changes of later geological times, the discussion being based largely on observations made during the work of the California survey. Whitney was struck by the appearance of recent desiccation in the West, as illustrated by the lake regions of the Great Basin, and from a study of the phenomena here met with as compared with those in other regions he was led to conclusions radically at variance with those commonly accepted by his co-workers. It will be remembered that in the work on the auriferous gravels he took the ground that there had been no appreciable change in elevation of the Sierras since the close of Cretaceous times, and he argued that the Tertiary auriferous gravels were laid down by the rivers of that period which flowed through broad channels, the present deep-cut V-shaped channels being due to the smaller volume of water which was the result of a decrease in annual precipitation.

Concerning such, he wrote:

> It is, as a general rule, safe to assume that where U-shaped valleys exist the perpendicular walls have an orographic origin and that those of V form have had that

[a] Recent work of A. Liversidge, the Australian mineralogist, confirms this view.

shape given to them by the débris piles which have accumulated against their sides. The farther we descend the mountain slope the less the grade and consequently the less the carrying power of the stream. Hence the valley which is U-shaped in the upper part of its course acquires more and more of a V form as it approaches the plain at the base of the range from which it heads.

Whitney thought to be able to trace, not to go too much into detail, a period of warmth and heavy precipitation followed by one of desiccation, but anticipated by one of cold and glaciation, the glaciers, however, being limited to the most elevated ranges of the Cordilleras. At the outset he announced himself as opposed to the "wild and absurd" ideas that had prevailed regarding glaciation in the Sierras, and stated it as his belief that here at least ice had played but an extremely subordinate part as a geological agent, though "there is no doubt that the great California range was once covered with grand glaciers, but little if at all inferior to those which now lend such a charm to the Swiss Alps."

In the discussion of the question he called attention to the fact that the Great Lakes of North America and most of those of other countries as well are included in areas underlain by Paleozoic rocks or those partly Paleozoic and partly Archean, and are due not to glacial erosion, but to orographic movements—Lake Superior, for instance, occupying a synclinal depression in Paleozoic rocks just along the edge of the Azoic series.

The Lake region of the Great Basin while likewise orographic in origin has become desiccated through climatic changes, he finding no evidence that there has been any essential alteration in the configuration or topography of the western side of the continent since the Glacial epoch—that is, since the time when the crests of the highest ranges were to some extent covered with snow and ice. Therefore, no part of the desiccation which appears to have taken place since that time can be due to orographic changes; the phenomenon must have been a climatological one.

The phenomenon of fiords he considered as due to aqueous erosion along mountainous coasts which have since become depressed.

It was Whitney's opinion, further, that the geological importance of the ice sheet had been greatly exaggerated. It seemed to him beyond question that the icebergs had played an important part in carrying and distributing the large angular bowlders which in many places rest upon the surface in such a manner as to show that they could not have been placed in their present position by running water or by a general ice sheet.

He regarded it as evident enough that the climate of northeastern America during the Glacial epoch was a period of greater precipitation than is now taking place, but that it was a period of intense cold he would not admit. Glaciation or a Glacial period was due merely to increased precipitation. In order that such precipitation should take place an increased evaporation from the land and water was necessary. This could be brought about only by a general increase of temperature, the amount of precipitation being the same; whether it would or not give rise to glaciers would depend upon temperature, which itself would be dependent upon local conditions which might or might not be due to elevation of land surfaces. His idea, in brief, was that while during the Glacial epoch over the entire globe there might be a period of sufficient warmth to produce the desired evaporation, the precipitation would fall as rain or snow, according to the local uplift or depression. That the glaciers are now retreating in nearly every instance he regarded as due not so much to a change in climate—at least, not to a gradual increase of temperature—but rather to a gradual decrease in the amount of annual precipitation. He felt that "The weight of the highest authorities is decidely against the theories of both Adhemar and Croll, from the standpoint of astronomical science; while it is believed that these theories are equally at variance with the conclusions of the most eminent climatologists of the present day. At all events, the evidence in favor of a cyclical recurrence of cold, or Glacial periods, sinks into insignificance when compared with that indicating a progressive diminution of temperature on the earth's surface during the geological ages, and from the very earliest time when land began to exist from the conditions of which light on this subject could be procured.

In this connection it may be mentioned that Whitney considered the movement of glacial ice due to water:

> Glacier ice is not simply ice, but a mixture of ice and water, and it is to the presence of the latter that the whole mass owes its flexibility. The larger the amount of water, other things being equal, the more easily the glacial mass moves. When the water increases so as to get the upper hand, the ice gives way with a rush and becomes an avalanche. * * * The extreme variation of the rate of motion of different glaciers coming down from the inland ice of Greenland is due to the different amounts of water which they have imbibed.[a]

Second Geological Survey of Pennsylvania, 1874–1887.

The rapid development of the economic resources of Pennsylvania, particularly coal, iron, and petroleum, during the years intervening between the publication of Rogers's final report (1858) and 1874, aroused a great public demand for more detailed knowledge of geological facts. An appeal was, therefore, made to the State legislature in 1873 for the establishment of a second geological survey. This culminated in 1874 in an enactment providing for the appointment of ten commissioners, having authority to appoint a State geologist "of ability and experience" who should, with ten competent assistants, make such investigations as might be required to elucidate the geology of the State and put the

[a] It should be noted that Whitney's ideas were reviewed in a somewhat critical manner by G. K. Gilbert in Science for March 9, 16, and 23, 1883.

results of this and previous work, of either individuals or surveys, into a convenient form for reference.

Acting under this authority the commissioners in 1874 appointed as State geologist J. P. Lesley, a topographer of the first survey under Rogers, and subsequently connected, in the capacity of topographer and geologist, with various private surveys—a one-time clergyman, and then professor of geology in the University of Pennsylvania. Annual appropriations were made, amounting during the thirteen years in which the survey existed to $545,000. Under these seemingly favorable auspices the second survey was inaugurated. With Lesley was associated from time to time, in one capacity or another, a considerable number of individuals, among whom mention may be made of C. A. Ashburner, C. E. Beecher, J. C. Branner, J. F. Carll, H. M. Chance, E. W. Claypole, E. V. d'Invilliers, L. G. Eakins, Persifor Frazer, F. A. Genth, C. E. Hall, T. S. Hunt, A. E. Lehman, Leo Lesquereux, A. S. McCreath, F. Prime, jr., J. J. Stevenson, I. C. White, Arthur Winslow, and G. F. Wright.

From the work of this organization has sprung the most remarkable series of reports ever issued by any survey. Up to and including 1887, when field work was practically discontinued, there had appeared some 77 octavo volumes of text, with 35 atlases, and a "Grand Atlas." These were followed in 1892 and 1895 by the three octavo volumes constituting the final report.

A very large portion of the work of this survey fell beyond the time limits mentally set for the present history. It may, however, be stated that the main energies of the organization were directed toward the solving of economic problems,[a] and, as was the case with the Rogers survey which preceded it, more attention was devoted to chemical and physical than to paleontological questions. Lesquereux, who had been responsible for what paleobotanical work was done under Rogers, was commissioned to extend his investigations, and in 1880 and 1884 issued three reports of text and one atlas on the Coal Flora. The strictly paleontological work done from 1875 to 1880 was that of J. J. Stevenson and I. C. White, along the West Virginia, Ohio, and New York borders.

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[a] I have been obliged for the last fourteen years to direct the State survey almost exclusively in an economic direction, so as to make the whole of every appropriation bring as much fruit to the business community as possible, neglecting, in what systematic geologists may possibly or probably consider a shameful manner, strictly scientific researches. Even when I have ordered long and extensive scientific researches (as in the case of the analyses of the Lower Silurian limestone series opposite Harrisburg) it has been, not in the spirit of transcendental science, but with the express intention to use the results directly as applied science to the economical demands of the State. It can hardly be understood by outsiders how completely a State bureau is shut up to this necessity.

Yours, respectfully, J. P. LESLEY.

In 1881 and 1883 Professor White studied the fossils of the middle belt of counties on the Delaware, Susquehanna, and the upper Juniata rivers. Professor Stevenson did the same for the Maryland border, while E. W. Claypole was commissioned to prepare a special report on all forms discoverable in the district of the lower Juniata.

The main energies of the survey were, as above noted, devoted to economic problems, with particular reference to the extent both geographic and geologic of the coal and petroleum formations. A great amount of good was undoubtedly accomplished, perhaps as much as one has a right to expect. Work in later years has, however, showed that the fundamental defect of the survey was lack of accurate topographical maps. This seems the more remarkable in view of the fact that the same defect became obvious during the progress of the Rogers survey, and further, in that Lesley was, himself, a topographer.

To quote Lesley's own words (manuscript), the facts of dominant importance which became impressed upon the Pennsylvania survey were as follows:

(1) The Paleozoic formations reach their maximum thickness in this State; and consequently admit of a greater differentiation than elsewhere into special groups of beds.

(2) The middle region of the State is magnificently plicated and eroded, exposing innumerable outcrops, connected in zigzags, and of immense length.

(3) No unconformable later deposits cover and conceal these outcrops, so that there is an unexampled opportunity for the study of variable thickness and changes of type.

(4) The topographical features are so dependent upon the lithology and structure that any geological survey of the region must be virtually a topographical survey.

(5) The geological areas are of great size and so clearly defined, and so distinct in character, that they naturally claimed and received each one a survey of its own. These areas are: 1, The Bituminous Coal field of the west and north; 2, the Anthracite Coal fields in the east; 3, the middle belt of Devonian and Silurian formations; 4, the Mesozoic belt of the south and east; 5, the South Mountain Azoic; 6, the Philadelphia belt of Azoic rock; and 7, the region of Glacial Drift.

(6) The natural section of the Bituminous Coal Measures, down the Monongahela and up the Allegheny rivers, relieved the study of that part of the Paleozoic system of all ambiguity.

(7) The great amount of mining done in the anthracite fields made that part of the survey peculiarly exact and correct.

(8) The great size and number of the brown hematite mines furnished unusual opportunities for the study of that kind of mineral.

(9) The great size and number of limestone quarries, exploited for the manufacture of iron and for fertilizing farms, opened to view every part of the great Siluro-Cambrian formation, the whole of the Lower Helderberg, all the Devonian, and most of the Carboniferous limestone beds.

(10) On the other hand, Pennsylvania is singularly destitute of workable veins of the precious metals. Its poverty in gold, silver, copper, and lead is extreme. It has but one important zinc deposit; and but one nickel mine.[a] In fact its Azoic regions as a whole are barren country, containing but a few small magnetic iron ore beds, in

[a] Not worked since 1891.

strong contrast to the adjoining Azoic region of northern New Jersey. What little white marble it possesses makes a narrow outcrop for a few miles along a single line. Some serpentine rock, a little chrome iron, one large soapstone quarry, and some kaolin deposits conclude the list of its Azoic minerals.

Practically viewed, the geology of Pennsylvania is wholly Paleozoic, on the most magnificent scale, with an unexampled wealth of anthracite and bituminous coal, brown hematite iron ore, limestone, rock oil, and rock gas; and to the study and description of these its geological survey has from first to last been devoted.

Little attention has been paid to the lithological study of the building stones of the State, or to their economic description. The entire State is a rock quarry. Every known building stone from the granites, gneisses, quartzites, and traps, to hearthstones, flagstones, brownstone, and limestone can be got with ease and with infinite abundance on lines of transportation. All the principal outcrops of these building stone formations have been located and their places in the Paleozoic series defined in the reports, with sufficiently precise descriptions of their qualities and uses; but beyond this the survey could not go.

Sketch of Lesley.

Lesley was born in Philadelphia in 1819, and graduated at the University of Pennsylvania in 1838, becoming almost immediately connected with the State geological survey under Rogers, in the capacity of topographer. In 1841, during the temporary suspension of this work, he entered upon the study of theology at Princeton, and was licensed to preach in 1844. He then went to Europe, where he studied in the University of Halle during the winter of 1844–45.

FIG. 96.—J. Peter Lesley.

Returning to America, he assumed the pastorate of a Congregational church in Milford, Massachusetts, but resigned in 1851 and owing, it is stated, to a change in his religious views, gave up the ministry altogether. Returning to Philadelphia, he soon became secretary of the Iron and Steel Association and of the American Philosophical Society, and prominent in geological matters, particularly those relating to iron and coal. Had he so chosen, he could undoubtedly have acquired a fortune, but, preferring science for science' sake, he put aside all offers of private gain and remained poor, often desperately so, to the end of his days.

He was a man of tall, lank, but commanding figure, and, according to his biographer, of impressionable and emotional nature, an enthusiast and optimist, but often lamentably melancholy, undemonstrative, and even cynical. A man of tremendous nervous energy, aggressive and outspoken, his writings are full of expressions which, for terseness and unpolished emphasis, are unequaled. Thus, in a letter to Powell relative to the coloring of maps and the names of the various formations, he wrote:

The fact is these English names are good for nothing in America and ought to be ignored. If I were an expert in profanity, I should say damn the text-books, Dana's, Le Conte's, and all of them. They are mere museums of embarrassments, so far as classification is in question. * * * Fortunately Pennsylvania is a very small corner of the United States, and I suppose it matters very little whether its structure appears on your map or not. But in heaven's name (I mean the heaven of geology), what do you gain by distinguishing a miserable subformation like the Permian (one or two patches) and not distinguishing an enormous subformation 5,000 feet thick like the Subcarboniferous?[a]

THE WORK OF F. V. HAYDEN AND F. B. MEEK.

Hayden and Meek in the Bad Lands, 1853-1866.

The reports of D. D. Owen and Dr. John Evans on the collections made by the latter in the *mauvaises terres* of the White River in 1849, as published in 1852, had attracted a great deal of attention, and in the spring of 1853 Dr. F. V. Hayden and F. B. Meek were employed by Prof. James Hall to visit the "Bad Lands" to make collections of fossils.

The party met at St. Louis on Saturday, May 14, 1853, where they found Dr. John Evans bent upon a similar errand under the direction of Dr. B. F. Shumard. Leaving St. Louis, the party proceeded by boat up the Missouri, reaching Fort Pierre—what is now the town of Pierre, in South Dakota—June 21, whence they proceeded by wagon into the Bad Lands proper. Here, in spite of the difficulty of holding the party together through fear of hostile Indians, they remained for a period of several weeks, returning to Fort Pierre on July 18. They brought with them a large and valuable collection, including mammalian remains which were investigated by Dr. Joseph Leidy.

The Cretaceous invertebrate fossils were studied by Professors Hall and Meek and described by them in a memoir published by the American Society of Arts and Sciences of Boston in 1854. This paper was accompanied by a brief vertical section by Meek, showing the order of superposition of the Cretaceous beds. As this is believed to be the first section of the region, it is here reproduced in full:

Section of the Members of the Cretaceous Formation as observed on the Missouri River, and thence Westward to the Mauvaises Terres.

Eocene Tertiary formation:

Clays, sandstones, etc., containing remains of Mammalia. The entire thickness of this formation in the Bad Lands is from 25 to 250 feet.

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[a] Some of Lesley's "digs" at his fellow-workers are masterpieces of their kind. Thus in Volume I of his final report, where attempting to describe the chaotic conditions existing on the earth during the earliest Archean times, and the intense chemical activity incidental to the deluges of "sour rain" falling upon the hot surface, he says (p. 53): "All this had taken place before the first age of which we have any geological monuments and is only known to God and Dr. Sterry Hunt, who has described it magnificently in his Chemical Researches."

Cretaceous formation:

5. Arenaceous clay passing into argillo-calcareous sandstone. 80 feet.
4. Plastic clay with calcareous concretions containing numerous fossils. 250 to 350 feet.

This is the principal fossiliferous bed of the Cretaceous formation upon the Upper Missouri.

3. Calcareous marl, containing Ostrea congesta, scales of fishes, etc. 100 to 150 feet.
2. Clay containing few fossils. 80 feet.
1. Sandstone and clay. 90 feet.

Buff-colored magnesian limestone of the Carboniferous period.

Hayden's Work on the Upper Missouri, 1854.

In the following spring (1854) Doctor Hayden again ascended the Missouri River, this time partly under the auspices of the American Fur Company. He spent two years on this expedition, during which time he visited the various portions of the Upper Missouri, being without any other means than what he earned or secured in various ways as he went along, and dependent even for subsistence entirely on such friends as he met in the country, among whom were Col. A. J. Vaughan, the Indian agent, and Mr. Alexander Culbertson, of the American Fur Company.

He traversed the Missouri River to Fort Benton and the Yellowstone to the mouth of the Big Horn, and also considerable portions of other districts not immediately bordering on the Missouri. As the boats of the fur company had to be towed in ascending the river, the progress was necessarily slow. The time thus occupied by the boats was utilized by Hayden on the shores, and as a result he traversed a considerable portion of the journey on foot.

The vertebrate remains collected on this trip were, as in a previous case, described by Doctor Leidy, mainly in papers read before the Academy of Natural Sciences of Philadelphia, while the invertebrates were described by Doctor Hayden himself in connection with Professor Meek. The collections, which were deposited partly with the Academy of Science of St. Louis and partly with the Academy of Natural Sciences of Philadelphia, contained a larger number of species than all those previously known from that country, many of them being new and of a remarkable character.

Hayden with Warren in the Sioux Country, 1856.

Early in 1856 Hayden returned to St. Louis, and on February 15 of that year received from Lieut. G. K. Warren, of the U. S. Corps of Topographical Engineers, an offer to report upon the Sioux country. This report was made, and in May of the same year Warren appointed him one of his assistants in the exploration of the Yellowstone River and the Missouri River from Fort Pierre to a point 60 miles north of the mouth of the Yellowstone.

The field work of this expedition began on June 28, the party returning to Fort Pierre on October 22, and reaching Washington in

November. In May, 1857, Hayden was again appointed geologist by Lieutenant Warren, this time on an expedition to the Black Hills. The party was organized at Sioux City in June and proceeded up the Loup Fork of the Platte, returning to Fort Leavenworth, Kansas, early in the following December.

Hayden with Warren in the Black Hills, 1857.

Hayden noted the occurrence of—

1. Metamorphic Azoic rocks, including granite.
2. Lower Silurian (Potsdam).
3. Devonian (?).
4. Carboniferous.
5. Permian.
6. Jurassic.
7. Cretaceous.
8. Tertiary.
9. Post-Tertiary and Quaternary.

In a preliminary report given by Warren in the American Journal of Science for May, 1859, attention was called to the important physiographic fact that the Niobrara River seemed "to run along a swell or ridge on the surface and to be practically without tributaries."

This would seem to be a recognition of the fact, though not the principle, that streams flowing from a mountainous country and laden with silt may, in their lower levels where the current is less rapid and the carrying power less, so deposit their load as to build up both the bottom and banks, and this until the stream actually occupies the crest of a ridge. The Platte River is, however, a better illustration of this than is the Niobrara. That portion of the channel running between steep bluffs he thought "must have originated in a fissure in the rocks which the water basins enlarged and made more uniform in size." This failure at this late day to realize that a stream may carve out its own channel can be excused only on the ground that Warren was not a geologist.

During the summer of 1858 Messrs. Hayden and Meek explored a portion of what was then called the Territory of Kansas. The route followed, as given by Hayden in his report published in the Proceedings of the Academy of Natural Sciences of Philadelphia, was as follows:

Meek and Hayden in Kansas, 1858.

From Leavenworth City on the Missouri, across the country to Indianola near the mouth of Soldier Creek and the Kansas River; thence up the north side of Kansas and Smoky Hill rivers to the mouth of Solomons Fork. Here they crossed the Smoky Hill, following it up on the south side to a point near the ninety-eighth degree of west longitude, from which point they struck across the country in a southwest direction to the Santa Fe road, which was followed northeastward to the head of Cottonwood Creek.

Leaving the road here, they went down the Cottonwood Valley some 30 miles, when they turned due east to Council Grove, from which place

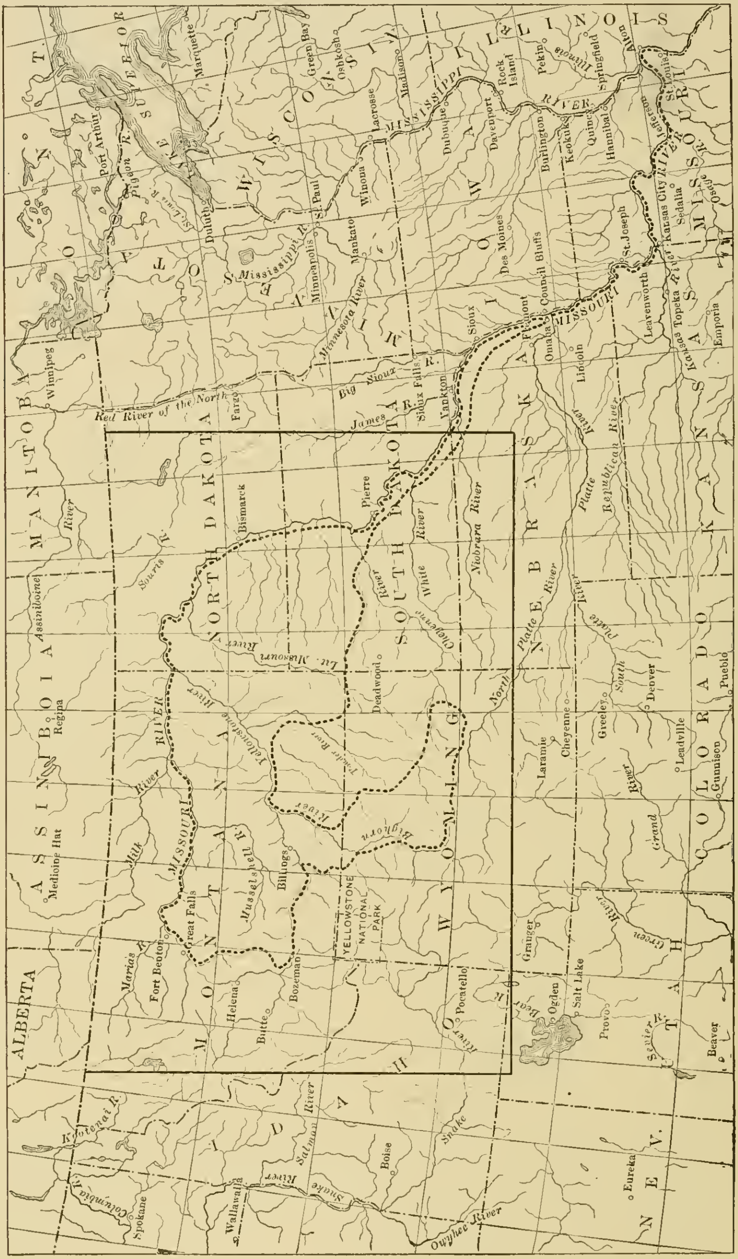


FIG. 97.—Map showing routes of Raynold's Expedition in 1859–60, and area covered by Hayden's report.

the Santa Fe road was followed southwest for about 24 miles to a watering place known as Lost Springs. Here they struck across the country in a northwest direction to Smoky Hill River again at a point nearly opposite the mouth of Solomons Fork. Thence the route lay down the south side of Smoky Hill and Kansas rivers to Lawrence, and thence across the Kansas in a northeastward direction to Leavenworth city. The explorations were very successful, and the results embodied in numerous papers in the Proceedings of the Academy of Natural Sciences of Philadelphia and elsewhere.

Hayden with Raynolds's Expedition, 1859.

In April, 1859, Capt. W. F. Raynolds was instructed to organize an expedition for the exploration of the country from which flow the upper tributaries of the Yellowstone River and of the mountains in which these tributaries and the Gallatin and Madison forks of the Missouri have their source. On April 22 Doctor Hayden was appointed surgeon and naturalist of this expedition. The party left St. Louis May 28, 1859, going up the Missouri to Fort Pierre, which point was reached about the middle of June. From here the route was westward and northwestward to the Yellowstone River by way of the Cheyenne, the Belle Fourche, and Powder rivers. The Yellowstone was reached near the mouth of the Big Horn about the middle of August. From the Yellowstone the expedition turned southward early in September and followed up the Big Horn, skirting the eastern edge of the Big Horn Mountains, finally going into winter quarters on Deep Creek, near the North Platte River, about the middle of October.

The following May (1860) explorations were resumed, the expedition going to Fort Benton, on the Missouri, by way of the North Platte, Wind, Snake, and Madison rivers. Fort Benton was reached July 14. On the 23d of July the return trip to Omaha was begun, the party proceeding by boat down the Missouri River to Fort Union, and from the latter point by land. Omaha was reached October 4, where the party disbanded.

The report of this last expedition, published early in 1869, comprised some 174 octavo pages, including 30 pages of paleontological notes by J. S. Newberry. It was accompanied by a colored geological map of the region north of the forty-second parallel and lying between the ninety-eighth and one hundred and fourteenth meridians (fig. 97).

Summary of Hayden's Early Work.

Some of the more important conclusions arrived at by Hayden as a result of observations on these expeditions are as follows: He announced in 1857 the discovery of Potsdam sandstone in the country about the headwaters of the Yellowstone, and in a preliminary publication in the American Journal of Science for 1861 described it as more or less changed by heat from beneath. The other formations noted were Carboniferous (including Permian?), red arenaceous deposits overlying the Carboniferous, but of uncertain age; Jurassic, Cretaceous, and Tertiary deposits. During the long interval that elapsed between the deposition of the earliest part of the Silurian and the commencement of the Carboniferous, he believed dry land to have prevailed over a large portion of the West, and he found no evidence of deep-water deposits until far up into the Cretaceous. Near the close of this epoch the waters of the great Cretaceous seas receded toward the present position of the Atlantic on the one side and the Pacific on the other, leaving large areas in the central West dry land with but a slight elevation above the sea level. He showed that the White River Tertiary deposits were younger than the Lignite, and that the older members of the western Tertiary were clearly separable into four divisions exclusive of the Pliocene of the Niobrara. He believed that the estuarian deposits ushered in the dawn of the Tertiary epoch and that they belonged to the Eocene period. The evidence of the fossils was regarded as indicating that a much milder climate prevailed throughout the West during the greater part of the Tertiary than at present—a climate somewhat similar to that of the Gulf States at the present day.

In an article on the Primordial sandstone of the Rocky Mountains, published in the American Journal of Science for 1862, he announced the finding of undoubted evidence of the existence of the equivalent of the Potsdam sandstone of the New York series in two important outliers of the Rocky Mountain chain. He pointed out the singular uniformity in the nature of the sediments and general lithological resemblance to the eastern type, but did not regard this as due to the currents bringing the material from the East. He thought, rather, that the uniformity was due to a similar uniformity on the part of the underlying rocks from which sediments were derived—that is, he believed that the source of all the sediments composing the Primordial rocks in the West could be traced to underlying rocks in the immediate vicinity. He noted the gradual thinning out of this Primordial sandstone toward the West, and quoted the observations of D. D. Owen in Minnesota, Whitney in Iowa, Safford in Tennessee, and Shumard in Texas as confirmatory. The lower secondary formations, on the other hand, as he pointed out, gradually increased in thickness.

He noted no unconformability in any of the fossiliferous sedimentary rocks of the Northwest from the Potsdam sandstone to the summits of the true Lignite Tertiary, but found proof of two great periods of disturbance, the one prior to the deposition of Potsdam sandstone, when the Azoic or granitic rocks were elevated to a more or less inclined position, and the other, much the more important, at the close of the Lignite Tertiary, when the "massive nuclei of the ranges were raised above the surrounding country."

In the American Journal of Science for 1862 Hayden had an important paper in regard to the period of elevation of the ranges of the Rocky Mountains near the sources of the Missouri River and its tributaries. He regarded the evidence as clear that the great subterranean forces which elevated the western portion of the continent were called into operation toward the close of the Cretaceous epoch, and that the gradual rising continued without a general bursting of the earth's surface until the accumulation of the Tertiary lignite deposits, or at least the greater part of them. Also, that after the fracture of the surface commenced and the great crustal movements began to display themselves, the whole country continued rising, though perhaps with intervening periods of subsidence, up to and even including the present period.

During the years of the civil war western exploration of all kinds was interrupted. Hayden served in the Federal army as a surgeon from 1862 until 1865, resigning to accept the position of professor of mineralogy and geology in the University of Pennsylvania, a position which he retained until 1872.

In the summer of 1866 he undertook a second expedition to the Bad Lands, this time under the auspices of the Academy of Natural Sciences of Philadelphia. In company with James Stevenson he left Fort Randall, South Dakota, August 3. The trip was made with a six-mule team and occupied fifty-two days, during which a circuit of six hundred and fifty miles was accomplished. The large and valuable collection of mammalian fossils was described by Leidy in his great work of upward of 450 large octavo pages and 30 plates, published under the auspices of the Academy of Natural Sciences of Philadelphia. The work began with an introduction of 12 pages on the geology of the Tertiary formations of Dakota and Nebraska, accompanied by a map. In this work Hayden pointed out the possibility of bridging over the chasm heretofore existing between the Cretaceous and Tertiary periods by means of transition beds belonging to the lignite series. He reiterated some of the statements made in previous writings, to the effect that, at the close of the Cretaceous period, the Rocky Mountain area was occupied by the waters of an ocean with perhaps a few peaks projecting. Near the close of the period the surface had reached an elevation so great as to form long lines of separation between the waters of the Atlantic on the East and those of the Pacific on the West, and then this great watershed began to rise above the surrounding country and the period of great fresh-water lakes was inaugurated. The elevation during the Cretaceous period he regarded as slow and gradual, but at about the close of the period or in the early part of the Tertiary the limit of tension in the crust was reached and long lines of fracture commenced which form the nucleus of the present mountain ranges, including the lofty continuous ranges with a granitoid nucleus along the eastern portion of the Rocky Mountains, as the Wind River, Big Horn, Laramie, or Black Hills. He showed that the Tertiary beds were in part deposited before the upheaval, as indicated by the inclination of the lignite beds.

Hayden's Second Expedition to the Bad Lands, 1866.

The lower Tertiary fossils included brackish-water forms, and he thought to trace the "history of the growth of the continent step by step from the purely marine waters of the Cretaceous ocean to the period when the mountain ranges were elevated," the ocean waters excluded and inclosed lakes formed, at first salt, but gradually freshened by influx from fresh-water streams. He stated further that the elevating forces acted throughout the Tertiary and post-Tertiary periods, and probably continue to act down to the present time. During the Tertiary period there existed at least four and possibly five of these fresh-water lakes in the West, two of which were of great extent. The deposits in these lakes formed the bad lands of the Judith, the great Lignite basin, the Wind River basin, and the White River group. A portion of this last, that in the region of the White River, he regarded as of Miocene age.

THE U. S. GEOLOGICAL AND GEOGRAPHICAL SURVEYS UNDER F. V. HAYDEN.

In the spring of 1867 Hayden, acting under the direction of the General Land Office, and with an appropriation from Congress amounting to $5,000, began his work as U. S. geologist in Nebraska, and in so doing laid the foundation for the U. S. Geological Survey as it exists to-day. Hayden was assisted during the first year by Dr. C. A. White and F. B. Meek. His first annual report comprised 64 octavo pages, and dealt largely with the possible occurrence of workable beds of coal within the State (decided in the negative); the loess, which he regarded as silt brought down by streams and deposited in a fresh-water lake, and considerations relative to the distribution of the Cretaceous and Tertiary deposits. In 1868 the appropriation of $5,000 was renewed and the field of work extended into Wyoming. In his report of 102 pages he called attention to the probable Tertiary age of all the coal of both Wyoming and Colorado. In 1869 $10,000 was appropriated and the field of work transferred to Colorado and New Mexico, the survey being at the same time placed under the direction of the Secretary of the Interior. His assistants for this survey were James Stevenson; Henry W. Elliott, artist; Persifor Frazer, mining engineer and metallurgist; Cyrus Thomas, entomologist and botanist; E. C. Carrington, zoologist, and B. H. Cheever, jr.

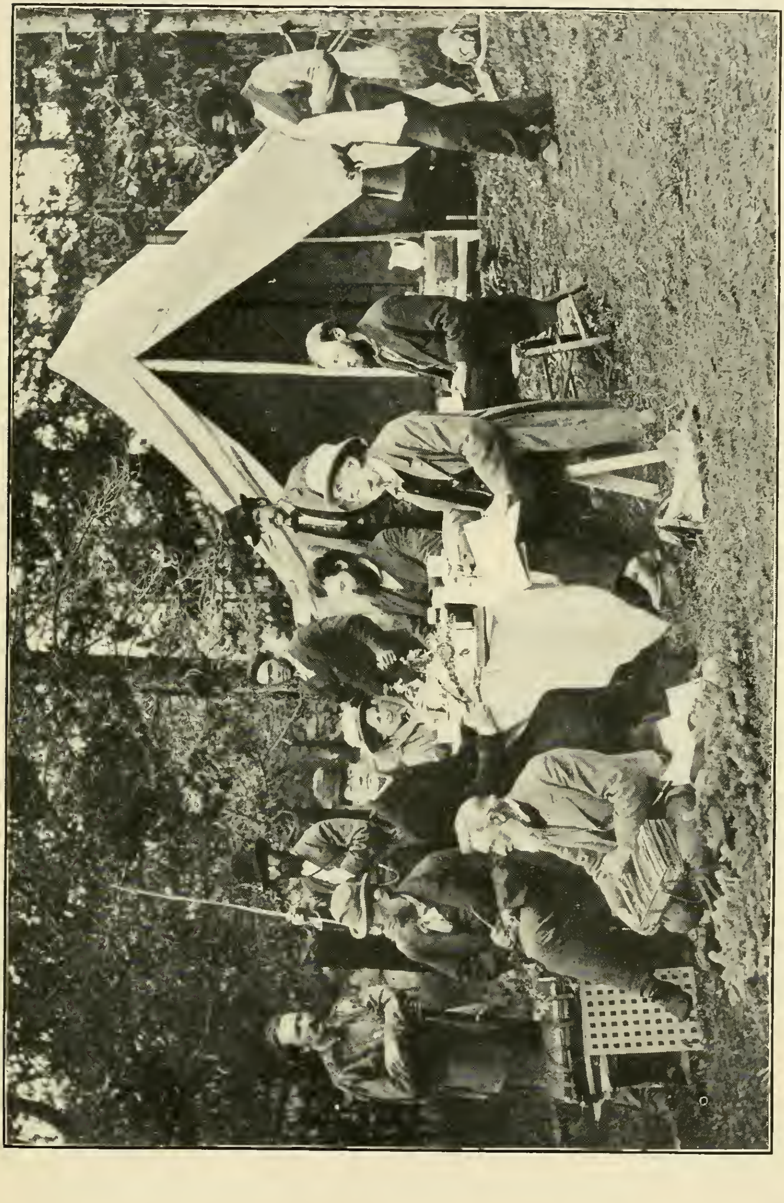
Work of Hayden in Nebraska, 1867.

Work of Hayden in Wyoming, 1868.

Work of Hayden in Colorado and New Mexico, 1869.

In this report he confirmed the statement made by him in the American Journal of Science for March, 1868—

that all the lignite Tertiary beds of the West are but fragments of one great basin, interrupted here and there by the upheaval of mountain chains or concealed by the deposition of newer formations.



Sir Joseph Hooker, Prof. Asa Gray, Mrs. Gray, Dr. R. H. Lamborn, Gen. Richard Strachy,
Mrs. Strachy, James Stevenson, F. V. Hayden.

HAYDEN FIELD PARTY AT LA VETA PASS, AUGUST, 1877.

He pointed out that the main range of the Rocky Mountains "is really a gigantic anticlinal and all the lower ranges and ridges * * * only monoclinals, descending steplike to the plains on each side of the central axis." Also that there were two kinds of ranges in the Rocky Mountain system—one with a granitoid nucleus, with long lines of fracture, and in the aggregate possessing a specific trend; the other with a basaltic nucleus, composed of a series of volcanic cones or outbursts of igneous rocks, in many cases forming saw-like ridges like those of the Sierras.

He found no evidences of any unconformity between the Cretaceous and lower Tertiary beds and no such changes in the sediments as would account for the sudden and apparently complete destruction of organic life at the close of the Cretaceous period.

He visited the Salt Lake Valley and examined the terraces and old shore lines of Great Salt Lake, describing the beds as of post-Pliocene or Quaternary age and correlating them with the terraces noted by him above the Wasatch Canyon. He found this series of beds so widely extended and so largely developed in Weber and Salt Lake valleys that he regarded it as worthy of a distinct name, and in consequence called it the Salt Lake group. He afterwards (in 1871) limited the name to the older beds, which he considered as of later Pliocene age, recognizing the more modern character of the terraces in which he found a great abundance of fresh-water shells.

The question of priority in this region having arisen between the King and Hayden surveys, it may be well to state that, according to Dr. A. C. Peale, Hayden's first work in the Salt Lake Valley was done in the years 1868, 1869, and 1870, and the results published in February, 1869, during the latter part of 1869, and the early part of 1871. The report of the field work of 1870 in Wyoming was first printed in 1871, and a second edition issued in 1872.

In 1870, with appropriations increased to $25,000, Hayden's field of operations was transferred to Wyoming and portions of contiguous territories. Stevenson, Elliott, and Thomas were with him as before, while W. H. Jackson, photographer; John H. Beaman, meteorologist; A. L. Ford, mineralogist; C. P. Carrington, zoologist, and Henry D. Schmidt, naturalist, were added to the scientific corps.

Work of Hayden in Wyoming, 1870.

The party outfitted at Cheyenne, in Wyoming, and proceeded northward along the eastern base of the Laramie range, exploring the Platte River as far as the Red Buttes, and thence passing across the divide to the Sweetwater; thence to the source of the Wind River Mountains, passing down Big and Little Sandy creeks to Green River, and exploring the northern slope of the Uinta Mountains. From Fort Bridger the route lay southward to Henrys Fork, which was explored down to its junction with Green River proper. From Green River Station the route followed the old stage route up Bitter Creek by way of Bridger Pass and the Medicine Bow Mountains, across the Laramie Plains, and through the Laramie Range by way of Cheyenne Pass, back to the point of departure.

Studies were made also along the line of the Pacific Railroad between Cheyenne and the Salt Lake Valley. No topographer accompanied the party, and the maps used were those constructed by the engineering department of the Army, which were, however, so inaccurate that to delineate the geology upon them in any but the most general way was practically impossible.

During this season Hayden worked out the sequence of the Carboniferous and Cretaceous rocks, and made the subdivisions of the latter into Dakota, Fort Pierre, and Fox Hill groups, which are still recognized. He remarked that some of the fossils found in southern Nebraska seemed to possess Permian affinities, though as they all extended down into the Coal Measures they could not be considered as characteristic, and therefore those rocks which he had previously mapped and colored as Permian should be relegated to the Permo-Carboniferous.

He noted the occurrence of Potsdam sandstone with *Obolella nana* and *Lingula* at South Pass on the south side of the Sweetwater. The massive granites as well as the intercalated stratified gneisses extending from South Pass City nearly to Pacific Springs were all regarded as of sedimentary origin. He showed that, near the close of the Cretaceous period, the ocean extended all over the area west of the Mississippi from the Arctic circle to the Isthmus of Darien. A little later the great watershed of the continent was marked out and the marine waters were separated into more or less shallow seas, lakes, and marshes, within which grew the abundant forests that went to form the coal beds.

From a study of the character of the vegetable impressions found in these beds, he argued that coal strata of contemporaneous origin may be purely marine, purely fresh water, or brackish, dependent upon local conditions. He pointed out that the sea had not had access to the Salt Lake Valley since middle Tertiary times, the sediments from 800 to 1,200 feet in thickness, called by him the Salt Lake group, being regarded as of Pliocene age and contemporaneous with the Niobrara, Arkansas, and Santa Fe groups, and of fresh water origin.

This report of Hayden was accompanied by special reports by Meek on the invertebrate paleontology, by Cope and Leidy on the vertebrate paleontology, by Lesquereux on paleobotany, and by Newberry on the ancient lakes of western North America. The volume marks the beginning of Cope's work with the Hayden survey, which resulted later in the production of the two monographs on the vertebrata of the

Cretaceous and Tertiary formations of the West, the latter, popularly known as "Cope's Primer," a pudgy volume of 1,009 pages and 134 full-page plates. With this year, too, began Jackson's work, which resulted in the production of what were at the time the finest landscape photographs ever taken, and which excited the wonder and admiration of geologists the world over.

In 1871, with an appropriation of $40,000, field operations were transferred to Montana and portions of adjacent territories, including what is now the Yellowstone Park. To the party of the year previous was added Anton Schönborn, topographer; G. N. Allen, botanist, and Dr. A. C. Peale, mineralogist. The route lay from Ogden, Utah, along the shore of Salt Lake to Willard City; thence through the Wasatch range to Cash Valley, and up the valley to the divide between the Salt Lake and Snake River basins. From this point they descended Marsh Creek to the Snake River basin and Fort Hall. Following the stage route to Virginia Junction, they crossed Black Tail Deer Creek near its source; thence down the Stinking Water to Virginia City; then, crossing the divide eastward to the Madison River, they descended the valley about 30 miles and crossed over the other divide to Fort Ellis, at the head of the Gallatin River. From Fort Ellis they passed again eastward over the divide between the Yellowstone and the Missouri to Bottler's ranch, where was established a permanent camp. A portion of the party then proceeded up the Yellowstone and entered the park area, surveying the mammoth hot springs on Gardners River, the Grand Canyon of the Yellowstone, the upper and lower geyser basins, and the lake. On returning to Bottler's ranch in August, they passed down the Yellowstone to Shields River and Fort Ellis, and thence down the Gallatin to Three Forks, up the Jefferson to the Beaver Head Branch and to

Work of Hayden Survey in Montana and the Yellowstone Park, 1871.

FIG. 98.—Edward Drinker Cope with skull of Loxolophodon cornutus.

Horse Plain Creek, and across the main Rocky Mountain divide to the headwaters of Medicine Lodge Creek, into the Snake River basin, to Fort Hall once more, and thence across the mountains to the head of Bear River and up the river to Evanston, on the Union Pacific Railroad, where the party disbanded.

As in years previous, Messrs. Cope, Lesquereux, Leidy, Meek, Newberry, and others served as collaborators in their especial fields. The hot springs and geysers were described in considerable detail, and the fact that they were but the feeble manifestations of dying volcanic energy recognized. It was shown that the mountain ranges passed over lie along the borders of synclinal valleys, which were originally the basins of fresh water lakes, and that all the ranges had a general north and south or northwest and southeast trend, and were here and there connected by cross chains; that the three main branches of the Missouri—the Madison, Jefferson, and Gallatin—flowed through valleys now extending to a width of 3 to 5 miles and now contracting to narrow canyons, the expansions of which had all been lake basins within late Tertiary and perhaps early quaternary times. The valleys were regarded as in part due to erosion, but for the most part as synclinal folds, the intervening mountain ridges being wedge-like masses of Carboniferous limestones.

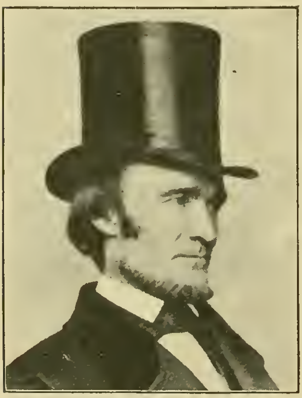


Fig. 99.—Fielding Bradford Meek.

The work done this year by Hayden and his party resulted in the setting aside of the Yellowstone region as a national park.

In 1872, with appropriations increased to $75,000, Hayden divided his force into two parties. The first, under his immediate charge, consisting of Adolf Burck, chief topographer; Henry Gannett, astronomer; A. E. Brown, assistant topographer; E. R. Wakefield, meteorologist; A. C. Peale, mineralogist; W. H. Holmes, artist, and W. B. Platt, naturalist.

Work of Hayden in Montana, 1872.

This division left Fort Ellis, Montana, and explored the headwaters of the Yellowstone, Gallatin, and Madison rivers in much more detail than had been done during the previous year.

The second or Snake River division, under the directorship of James Stevenson, included Frank H. Bradley, chief geologist; W. R. Taggert, assistant geologist; Gustavus R. Bechler, chief topographer; Adolph Herring and Thomas W. Jaycox, assistant topographers; William Nicholson, meteorologist; John M. Coulter, botanist; Dr. Josiah Curtis, surgeon and naturalist, and William H. Jackson, photographer. This division visited the Snake River or Lewis Fork of the Columbia in Idaho and Wyoming territories, a region up to that time little known. The Teton Mountains—a prominent range—were ascended by Stevenson on this trip, this being the first time, it was claimed, that the feat had been accomplished by a white man.

Professors Leidy and Cope spent a large part of the summer in studying the ancient lake basins in the interior, and obtained the materials described in Volumes 1 and 2 of the quarto final reports. Lesquereux spent several months in exploring the coal beds to ascertain their geological position, and F. B. Meek and H. M. Bannister studied the invertebrates.[a]

From a preliminary study Lesquereux was inclined to call the lignite beds mostly Eocene. Meek regarded them as Upper Cretaceous, passing through transition beds to the Eocene, and Cope regarded them as Cretaceous. Hayden in this report gives, himself, a brief review of the opinions held and the evidence on which same is based, and concluded that the deposition of the lignite strata began during the latter portion of the Cretaceous period and continued on into Tertiary time without any marked physical break, so that many of the Cretaceous types, especially of the vertebrates, may have lingered on through the transition period even into the Tertiary epoch.

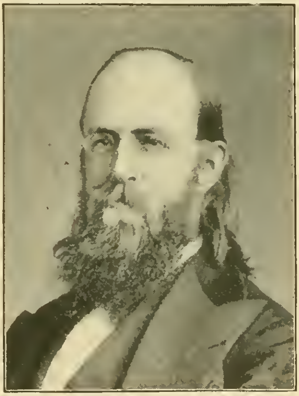


Fig. 100.—Frank Howe Bradley.

In this report Hayden called attention to one feature in the geological structure of the mountains of Montana observed by the survey during the past season for the first time and not noticed in such a marked degree in any other portion of the West, and that is the inversion of the sedimentary beds, so that the oldest incline at a greater or less angle on those of more modern ages. As illustrative of this, he gave an east and west section across the Flathead Pass in the East Gallatin range, the central portion of this range being composed of Carboniferous limestone standing nearly vertically. A similar illustration of inversion was given by Peale in his report on the geology of Jackass Creek on the upper Missouri River.

Another point to which Hayden called attention in this report was the fact that the streams "seem to have cut their way directly through the mountain ranges instead of following synclinal depressions," indicating, to his mind, that they began the process of erosion at the time of the commencement of the elevation of the surface. (See also Powell, p. 566.) The period of intense volcanic activity manifested in the Yellowstone region he thought to have probably commenced somewhere during later Miocene or early Pliocene epochs.

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[a] Bannister also reported on a geological reconnaissance along the Union Pacific Railroad this same year.

With Cope, Leidy, and Marsh all in the field of vertebrate paleontology at one time, it is not strange that a spirit of rivalry, if not of personal jealousy, should have arisen. This found expression in numerous instances which at this date are only amusing, however serious they may at the time have seemed to those most interested. Thus, Cope in 1868 described and figured remains of a marine saurian from the Cretaceous of Kansas, to which he gave the name of *Elasmosaurus platyurus*. Leidy, ever on the alert, made a reexamination of the materials, and at the meeting of the Philadelphia Academy on March 8, 1870, announced that the remains were, in reality, those of an Enaliosaurian and closely allied to Plesiosaurus, and, further, that Cope's error in identification lay in his having described the animal—the skeleton of which was without a skull and quite incomplete—in a reversed position from the true one.[a]

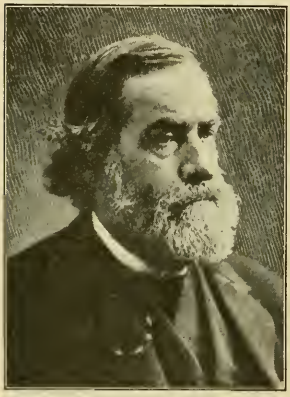

FIG. 101.—Joseph Leidy.

Work of Hayden Survey in Colorado, 1873-1876.

In 1873, with appropriations the same as for the previous season, the field of operations was transferred to Colorado, this in part owing to the expense of transportation, subsistence, and labor in regions so remote as those of the upper Missouri, and in part to the hostility of the Indians. The party rendezvoused at Denver. The area decided upon to be surveyed comprised the eastern portion of the mountainous part of Colorado, and was divided into three districts known as the North, Middle, and Southern. The personnel and their assignments were as follows:

The first or Middle Park division, directed by A. R. Marvine, assistant geologist, with G. R. Bechler, topographer, and S. B. Ladd, assistant topographer. The second or South Park division, with Henry Gannett as topographer in charge; Dr. A. C. Peale, geologist;

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[a] Another illustration of hasty work—in this case through fear of anticipation by Marsh—is furnished by Cope while with the Hayden survey in Wyoming in this year (1872). Finding certain fragmentary vertebrate remains which he believed to represent new species, he actually sent the following telegram to the Philadelphia Academy in order to secure priority of publication:

BLACK BUTTES, WYOMING, *Aug. 17, 1872.*

I have discovered in southern Wyoming the following species:

Loxolophodon Cope. Incis. 1, one canine tusk, pm. 4, with one crescent and inner tubercle; molars 2, size gigantic. *L. cornutus*, horns tripedral, cylindric; nasals with short convex lobes. *L. furcatus*, nasals with long spatulate lobes. *L. pressicornis*, horns compressed subacuminate.

EDWARD D. COPE,
U. S. Geological Survey.

W. R. Taggert, assistant geologist; Henry W. Stuckle, assistant topographer, and J. H. Batty, naturalist. The third or San Luis division was in charge of A. D. Wilson, topographer, with George M. Chittenden, assistant topographer, and Dr. F. M. Endlich, geologist.

The work of this year extended as far westward in Colorado as Middle Park, the Elk Mountains, and the San Luis Park. It was during this season's work that the peculiar examples of subaerial erosion of Monument Park in Colorado were described and figured, which have so frequently served the purpose of reproduction in the text-books. The wonderful instances of complete overturning of immense groups of beds, as illustrated in the Elk Range, were again referred to, attention being called to the fact that for several miles there is a double series from the Silurian up to the Cretaceous, inclusive, which had been thus inverted. In this report, too, were given the examples of inversion in the Snow Mass Range and the view on Roches Moutonnés Creek, both of which have served their purpose in the text-books of Dana and Le Conte.

FIG. 102.—Frederic Miller Endlich.

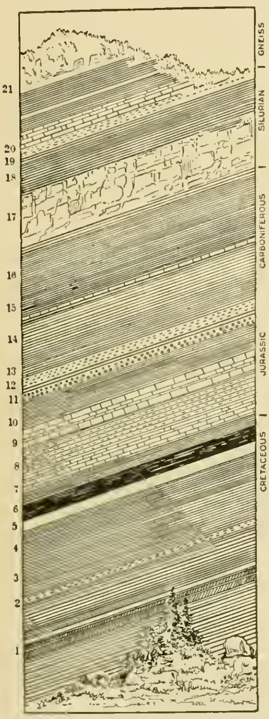

FIG. 103.—Inverted beds of Jackass Creek. (After A. C. Peale.)

The question of the age of the lignite beds occupied the attention of nearly all the workers in the field (see p. 647). Lesquereux, in his chapter on the lignite flora, argued in favor of the Eocene and Miocene age of the beds. Though not denying the presence of animal Cretaceous remains in the lignite strata, he regarded the "presence of some scattered fragments of Cretaceous shells as of little moment in comparison with the well-marked characters of the flora." Meek's invertebrate work, moreover, he regarded as rather in favor of the Tertiary hypothesis. To Cope's conclusions "that a Tertiary flora was contemporaneous with a Cretaceous fauna, establishing an uninterrupted succession of life across what is generally regarded as one of the greatest breaks in geological time," he took exception, as it did not appear to exactly conform to facts.

During the years 1874 to 1876 work under essentially the same conditions was continued by the Hayden survey throughout Colorado, the appropriations being $75,000 annually, with the exception of 1876, when they dropped to $65,000. The individual work of Hayden himself becomes gradually less conspicuous in the reports issued, owing to the increased amount of administrative work.

FIG. 104.—Albert Charles Peale.

In 1874 the party under direction of A. R. Marvine was engaged in the southern portion of North Park; that under Dr. A. C. Peale in the region bounded on the north by the Eagle and Grand rivers, on the east by the one hundred and seventh meridian, on the west by the State line, and on the south by latitude 38° 20′. The third division under A. D. Wilson, with F. M. Endlich, geologist, was assigned to what is known as the San Juan district, and the fourth, under the immediate direction of Doctor Hayden, with W. H. Holmes as artist and geologist, to the Elk Mountain region.

In the report for 1874 Hayden devoted considerable attention to the stratigraphic position of the Lignite group, a discussion of which may be referred to later. Perhaps the most striking feature brought out in the work of this year was that relative to the Elk Mountains. This range was regarded by Hayden as a grand illustration of an eruptive range, "the immense faults, complete overturning of thousands of feet of strata, and the great number of peaks, all composed of eruptive rocks," indicating to him periods of violent and catastrophic action. The great thickness of sedimentary strata which had been carried to the loftiest points of the axial ridge in a nearly horizontal position he thought might be explained on the supposition that at one time the sedimentary mass rested on a floor of pasty or semipasty granite, and that the forces in the interior were struggling to find vent and carried upward the entire overlying mass. This description is of interest when taken in connection with one by Marvine the year previous as showing the gradual inception of the laccolithic idea afterwards worked out in detail by Holmes, Peale, and Gilbert, to which I will now refer.

FIG. 105.—Archibald Robertson Marvine.

In describing the Sierra La Sal south of the Gunnison in the report for 1875, Peale compared them in structure with the Elk Mountains—that is, as of eruptive origin. "By this," he wrote, "I mean that the sedimentary strata have been lifted up by eruptive rock which has broken through them in some places, and in others is seen only as the result of subsequent erosion." As illustrative of this, he gave the figure reproduced here. (Fig. 106.)

The idea thus advanced seems to have been contagious, for in the same report Holmes described the Sierra El Late as formed of a number of distinct bodies of trachytic rock that had reached their present horizon through closely associated vents, frequently bending up the sedimentary rocks at a high angle around the borders, the upturned strata including the lower part of the Middle Cretaceous shales and portions of the Dakota sandstone. His observations tended to show, to quote his own words, "that there had been a sort of absorption, so to speak, of the shales, and that at least half of the space through which the trachyte is distributed is occupied by the crushed and metamorphosed fragments of shale. As a consequence the height of the arch—such as may once have existed—would not equal the height of the trachytic mass, as only the higher layers of shale extend entirely over it. His idea regarding the formation of this mountain can be best understood by reference to fig. 107, copied from Plate 46 in the report for 1875.[a] (See further on p. 622.)

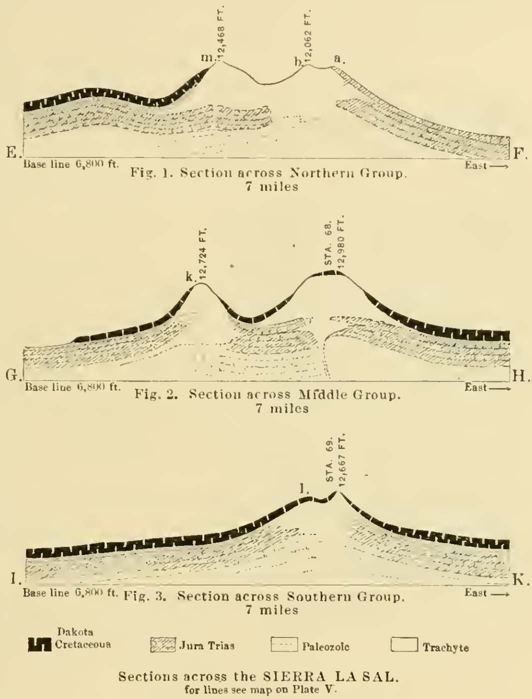

FIG. 106.—(After A. C. Peale.)

[a] The views regarding this method of mountain formation were subsequently summed up by Peale in an article, On a Peculiar Type of Eruptive Mountains in Colorado, which was published in No. 3 of the Bulletins of the Geological Survey, May 15, 1877.

In the season of 1876 C. A. White was at work in northwest Colorado, including the area lying between the Uinta and Park ranges. F. M. Endlich was engaged in the survey of the White River district, A. C. Peale of the Grand River district, and W. H. Holmes of the Sierra Abajo and West Miguel mountains.

In the interval between the issue of the reports for 1875 and 1876 Hayden, at the suggestion of King, had decided to call the transition group, heretofore referred to by him as Lignitic and the exact geological position of which was still in dispute, the *Laramie* group.

The report of this year contained little that is new or striking, the work resulting mainly in an extension of our knowledge of the geographic range of various geological formations. White, working in the Uinta region, aptly compared the structure of Junction Mountain to a displacement which might be illustrated by the action of a large punch worked by machinery, the perforated heavy iron plates being somewhat torn in places and nowhere clearly cut through in the process of punching. The work of White this year as a whole confirmed the view held by Hayden that these lignitic or Laramie beds, as they are now called, are of a transitional nature.

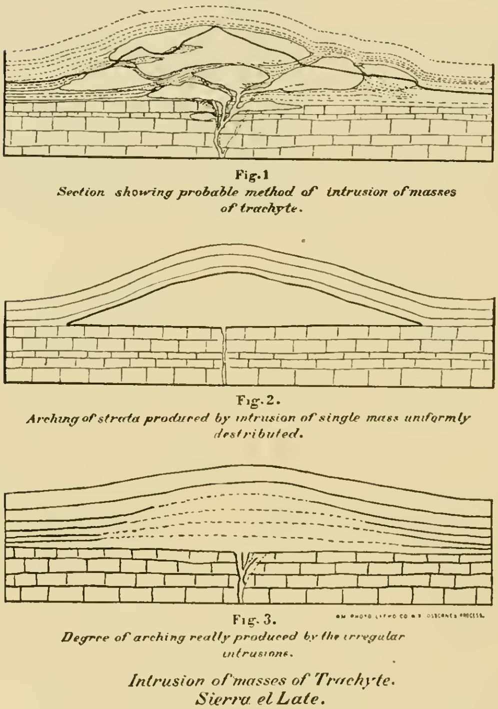

FIG. 107.—Sections across the Sierra el Late. (After W. H. Holmes.)

The field work for Colorado was completed in 1876. The following year (1877) the work was extended northward into Idaho and Wyoming. The geological work was, as before, assigned to Drs. F. M. Endlich and A. C. Peale, with the addition of Orestes St. John. Endlich worked in the Sweetwater region, Peale in the Green River district, and St. John in the Teton district.

Work of Hayden in Idaho and Wyoming, 1877.

S. H. Scudder spent two months of the year in Colorado, Wyoming, and Utah in collecting fossil insects, which were subsequently described in the thirteenth monograph of this survey. Sir Joseph Hooker, director of the Kew Gardens, England, and Prof. Asa Gray, of Cambridge, Massachusetts, accompanied the party for a time, making valuable botanical collections.

St. John noted the overturned character of a portion of the Caribou Range and made numerous sections across the Teton Range. Peale noted that in the region of the Blackfoot Basin the structure was that of a series of anticlinal and synclinal folds, the streams sometimes occupying the synclines and sometimes the monoclines. Also that there were at least three parallel anticlinal axes having the general direction northwest and southeast.

Hayden's twelfth and last annual report, bearing date of 1879 (1883), was issued in the form of two volumes of upward of twelve hundred pages, and included the work of the corps for the field season of 1878 and the office work until the closing up of the survey, which, by law, took effect June 30, 1879.

Work of Hayden in Wyoming, 1878.

The headquarters of the survey were at Cheyenne, Wyoming, as in previous years, and but four parties organized. The geological work was under the charge of W. H. Holmes, A. C. Peale, and Orestes St. John, and the paleontological work under Dr. C. A. White. Mr. Holmes made a general survey of the park, while Peale, assisted by J. E. Mushback, was occupied in making detail studies of the geyser and hot-spring localities.

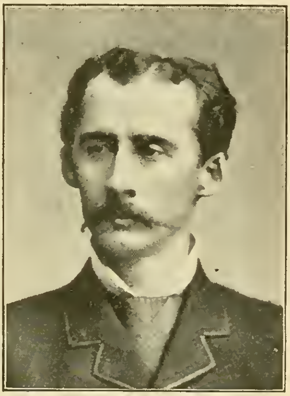

Fig. 108.—William Henry Holmes.

The party, with St. John as geologist, surveyed the Wind River Mountains and a portion of the Wyoming and Gros Ventre ranges. The work of the topographic party in the Wind River and Grand Teton regions was hampered by their being robbed of all their animals and a portion of their outfit by hostile bands of Indians.

During the summer of 1877 Prof. S. H. Scudder, with a party, visited the Tertiary lake basin at Florissant and made an extensive collection of fossil insects, the published descriptions of which have made this region classic.

The two volumes mentioned are almost monographic as far as the hot springs and geysers are concerned, and are rendered unusually attractive for their time by the sketches and panoramas of Holmes. Peale gave a detailed description of all the springs and geysers of any importance found in the park, describing and tabulating over 2,000 of the former and 71 of the geysers. Holmes's report was accompanied by some brief petrographic descriptions by Capt. C. E. Dutton.

Dr. F. V. Hayden was born at Westfield, Massachusetts, September 7, 1829. His father dying when he was but ten years of age and his mother marrying again, he went at the age of twelve to live with an uncle in Philadelphia, where he stayed until he was eighteen, beginning when he was sixteen to teach during the winter months in the district schools of the neighborhood. When eighteen, ambitious for an education and without money, he walked to Oberlin and laid his case before President Finney, of Oberlin College, who gave him such encouragement and sympathy that he set about preparing himself for college, working meanwhile at whatever he found to do to pay for his support and tuition.

Sketch of Hayden.

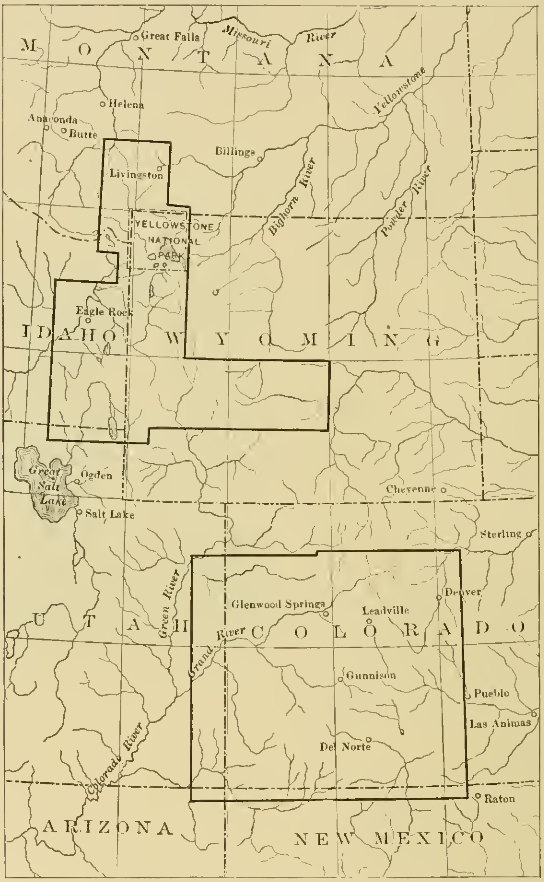

FIG. 109.—Showing areas surveyed and mapped by the Hayden Surveys, 1870–78.

He entered college and graduated in 1850, paying all his own expenses from the time he entered until graduation. These facts are mentioned, since they show the character of the man and enable one to understand better the causes of his success in after life. It is important to note, however, that, owing to his shyness and diffidence, his fellow students did not predict for him a prominent career, notwithstanding his acknowledged scholarly habits.

After graduating he studied medicine and received the degree of M. D. in 1853 at Albany, New York. While here he became acquainted with Prof. James Hall, and in the spring of 1853, together with F. B. Meek, went to the Bad Lands of the upper Missouri to make collections, as already noted. This trip marked the beginning not only of his scientific career but also that of his association with Meek, which lasted until the latter's death in 1876, and, incidentally, furnished an example of uninterrupted collaboration without a counterpart in the history of American geology.

FERDINAND VANDIVEER HAYDEN.

Director of U. S. Geological Survey of the Territories.

Hayden's scientific career, so promisingly begun, was, however, interrupted by the outbreak of the civil war, when he promptly volunteered, entering the Union army as an assistant surgeon and gradually rising to become post-surgeon and surgeon in chief to the Twenty-second Division of Cavalry. In June, 1865, he resigned from the army, but was subsequently breveted lieutenant-colonel for meritorious conduct. In the same year he was elected professor of geology and mineralogy in the University of Pennsylvania, holding this chair until 1872, when he was forced to resign, owing to his rapidly increasing duties in connection with the Geological Survey.

In 1879, after the consolidation of the various surveys, Doctor Hayden was appointed one of the geologists on the new organization. During the next four years his time was devoted mainly to the completion of the business and final publication of the reports of the Geological and Geographical Survey of the Territories. His health began failing soon after his acceptance of this position, and in June, 1882, at his own request, he was relieved from the work of supervision of printing the reports and assigned to duty in the field, spending the summers of 1883–1886 in Montana. His disease (*locomotor ataxia*), however, grew steadily upon him, and in 1886 he resigned on account of complete incapacity for duty, thus closing a career of nearly thirty years of actual service as naturalist, surgeon, and geologist in connection with the Government.

The apparent diffidence which impressed Doctor Hayden's fellow-students at Oberlin, and led them to be doubtful as to his future course in life, characterized his maturer years, and to those not well acquainted with him made it difficult to account for his success. However, enthusiasm, perseverance, and energy were qualities equally characteristic of him all his life, and what seemed to be diffidence was largely the result of his nervous temperament. The secret of his success is to be found in his enthusiastic frankness and his energetic determination to carry through whatever he undertook. He was absorbed in the work of the Geological Survey and bent all his energies to its success. Excitable in temperament and frequently impulsive in action, he was generous to a fault, and, although ever ready to defend what he believed to be right, he was willing upon the presentation of evidence to modify his views.

He was always careful to give due credit to all who had worked in the fields he afterwards explored. In one of his reports, speaking of those who had preceded him, he says:

> Any man who regards the permanency or endurance of his own reputation will not ignore any of those frontiersmen who made their early explorations under circumstances of great danger and hardship.

The same spirit actuated him in his treatment of his subordinates and co-workers. His honesty and integrity were undoubted and his work for the Government and for science was a labor of love.

The following extract is from an article by Dr. Archibald Geikie, then director of the Geological Survey of Great Britain:

> There can be no doubt that among the names of those who have pioneered in the marvelous geology of western North America that of F. V. Hayden will always hold a high and honored place. This place will be his due not only because of his own personal achievements in original exploration. His earlier work exhibits much of that instinctive capacity for grasping geological structure which is the main requisite for a field geologist. He had a keen "eye for country." But he likewise possessed the art of choosing the best men for his assistants and the tact of attracting them to himself and his corps. In this way he accomplished much excellent work, keeping himself latterly in the background so far as actual personal geological investigations were concerned, and contenting himself with the laborious task of organization and supervision while he encouraged and pushed forward his coadjutors.[a]

In an obituary notice of Doctor Hayden, read before the American Philosophical Society, Prof. J. P. Lesley, who had known him for many years, pays him the following tribute:

> He represented in science the curiosity, the intelligence, the energy, the practical business talent of the western people. In a few years they came to adopt him as their favorite son of science. He exactly met the wants of the Great West. There was a vehemence and a sort of wildness in his nature as a man which won him success, cooperation, and enthusiastic reputation among all classes, high and low, wherever he went. In the wigwam, in the cabin, and in the court-house he was equally at home, and entirely one with the people. He popularized geology on the grandest scale in the new States and Territories. He easily and naturally affiliated with every kind of explorer, acting with such friendliness and manly justice toward those whom he employed as his coworkers that they pursued with hearty zeal the development of his plans.
>
> In dealing with the public men of the country he was so frank, forcible, and direct that it was impossible to suppress or resist him. He had the western people at his back so heartily and unanimously that he was for a long time master of the scientific situation at Washington. He was a warm personal friend of some of the highest officials of the Government, who never failed to support strenuously and successfully his surveys.
>
> I think that no one who knows the history of geology in the United States can fail to recognize the fact that the present magnificent United States Geological Survey, now under the direction of Major Powell, is the legitimate child of Doctor Hayden's Territorial surveys.

According to Cope,[b] the Sioux Indians gave to Hayden the name "The-man-who-picks-up-rocks-running," a name which was certainly descriptive of the manner in which much of his work was necessarily done. The same writer states that at one time, when engaged in the exploration of the Laramie beds of the upper Missouri, he was pursued and finally overtaken by a band of hostile Indians. Finding him armed only with a hammer and carrying a bag of rocks and fossils, which they emptied out and examined with much surprise and curiosity, they concluded he was insane and let him alone.

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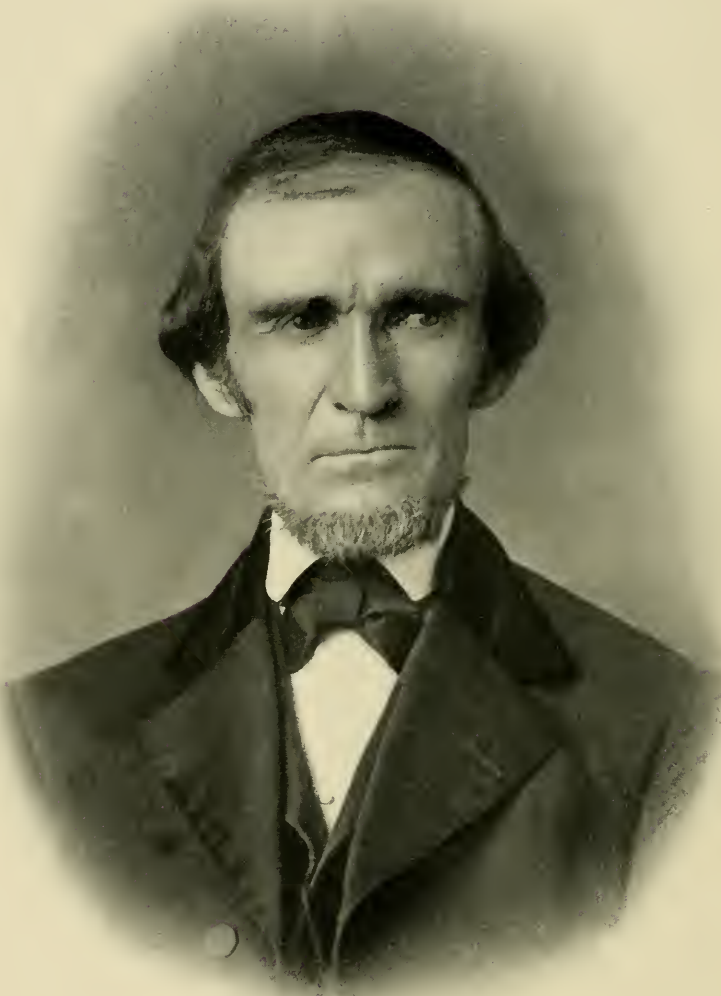
[a] Nature, XXXVII, February, 1888, pp. 326–327.

[b] American Geologist, 1, 1888, p. 110.



FIELDING BRADFORD MEEK.

Paleontologist.

F. B. Meek, Hayden's collaborator, was born of Irish parentage in the city of Madison, Indiana, in 1817, and during 1848-49 served as assistant to D. D. Owen on the surveys of Iowa, Wisconsin, and Minnesota. Afterwards (from 1852-1858) he was assistant to James Hall at Albany, New York, and for a portion of the time connected with the geological survey of Missouri with Prof. G. C. Swallow. As noted elsewhere, he became early associated with Hayden, and, though refusing to become officially connected with the survey, was tacitly associated with him until the time of his death. Indeed, all the invertebrate fossils collected by Hayden in his western explorations were studied and the results prepared for publication by Meek, although appearing mainly under the joint name of Meek and Hayden.

Sketch of Meek.

On leaving Albany in 1858 Meek came to Washington, where he resided during the remainder of his life, having a room in the Smithsonian building. He was moderately tall and rather slender in build, with a dignified bearing, though quite diffident. During the latter part of his life he was also deaf, which caused him to avoid social gatherings almost altogether. He was never a man of robust health; indeed, during a large part of his life he was more or less an invalid. Genial, sincere, pure-minded, and honorable, such are the adjectives applied to him by his biographer. With the exception of James Hall, he is perhaps the most widely known of American paleontologists. Indeed, had Meek possessed the tremendous physique of Hall or the nervous energy of Hayden, he might have stood alone head and shoulders above most, if not all, his contemporaries. As it was, he did his best work only in the service of, or in collaboration with others, never as an organizer or leader. It is true that in his first expedition (under the patronage of Hall) to the Bad Lands he outranked Hayden, and that in numerous instances his work was of a higher order. Yet his mildness of character and lack of disposition to assert himself, until perhaps too late, caused him to almost invariably occupy a second place in any organization with which he was connected.

THE FORTIETH PARALLEL SURVEY UNDER CLARENCE KING.

In 1867 there was established by Congressional action, and almost wholly through the personal efforts of Clarence King, what has since been known as the Geological Survey of the Fortieth Parallel. This, though subject to the administrative control of Gen. A. A. Humphrey of U. S. Engineers, was under the immediate direction of King, to whom must be given almost the entire credit of its inception and successful execution.

King's Survey of the Fortieth Parallel, 1867-1877.

The immediate excuse for the survey was the desirability of ascertaining the character of the mineral resources of the country to be traversed by the Pacific Railroad. The region explored, however, was a very extended one, reaching from the eastern Colorado range to the Sierra Nevadas, with an average width of about 100 miles along the fortieth parallel.

The plan of the work, as outlined by Emmons,[a] contemplated making a topographical map of the region on the general plan of those made at the present time, i. e., one on which the topography was indicated by contour lines rather than hachures on the hillsides, the then prevailing custom. The scale adopted was 4 miles to the inch, and the original area divided into three rectangular blocks or atlas sheets, each about 165 miles in length by 100 miles in width. Subsequently two more blocks were surveyed, making the total area surveyed and mapped some 82,500 square miles.

The party, according to the author above quoted, rendezvoused in California in the early part of the summer of 1867, and began their work at the east base of the Sierras in August, with J. D. Hague, Arnold Hague, and S. F. Emmons as geological assistants. Though few in number, the force was beyond question the best equipped of any that had thus far entered the field of American geology.

The winter of 1867–68 was spent at Virginia City, Nevada, in the study of the Comstock Lode, the mines of which, then but 1,000 feet in depth, had already produced some one hundred millions of dollars. The results of this work appeared in J. D. Hague's monograph, The Mining Industry, published in 1870.

During the season of 1868 the work of the survey was pushed eastward entirely across the Great Basin to the western shore of Great Salt Lake. In that of 1869 the desert ranges of Utah, the Wasatch, and the western end of the Uinta ranges were surveyed. This completed the work as originally planned, and with headquarters at New Haven, the task of working up the collections and platting the topographic and geologic notes was undertaken.

This work was, however, abruptly interrupted in the summer of 1870 by telegraphic orders from General Humphrey, directing the party to once more take the field, Congress, without solicitation, having appropriated money for the continuation of the survey. It being then too late in the season to prepare the necessary outfit for work in the high mountain regions east of the Wasatch, the season was devoted to a study of the extinct volcanoes, Mount Shasta, Mount Rainier, and Mount Hood. Among the results of this study was the discovery of the first-known active glaciers within the limits of the United States.

During the summers of 1871–72 the survey was carried eastward to the Great Plains and included an examination of the Eocene beds of

[a] Presidential Address, Geological Society of Washington, 1896.

the Green River Basin, the Uinta and Elk Mountains and the intervening Mesozoic and Tertiary valleys of the North Park and the Laramie Plains, the Medicine Bow Range, and the northern extension of the Front Range.

The survey made no annual or preliminary reports, and as the thorough study of the data collected consumed several years of time, some of the results obtained were anticipated by other organizations through priority of publication.

The published reports, which appeared in the form of quarto volumes, named in the order of their appearance, were: Vol. III, Mining Industry, by James D. Hague, 1870; Vol. V, Botany, by Sereno Watson, 1871; Vol. VI, Microscopical Petrography, by Ferdinand Zirkel, 1876; Vol. II, Descriptive Geology, by Arnold Hague and S. F. Emmons, 1877; Vol. IV, consisting of Parts 1 and 2, Paleontology, by F. B. Meek, James Hall, and R. P. Whitfield, and Part 3, Ornithology, by Robert Ridgeway, 1877; Vol. I, Sytematic Geology, by Clarence King, 1878; and Vol. VII, Odontornithes, by O. C. Marsh, in 1880. The first volume was accompanied by a geological atlas containing ten large double maps.

Fig. 110.—Robert Parr Whitfield.

To properly summarize the work of the survey, as made known in these volumes, is a practical impossibility in the space that can be devoted to it. It was noted that, in the grand total of 120,000 feet of sedimentary accumulations found, the main divisions of Archean, Paleozoic, Mesozoic, and Cenozoic were all distinctly outlined by divisional periods of marked unconformity. Considered as a whole, there was a noteworthy fullness in the geological column, none of the important stratigraphical time divisions being wholly wanting, excepting some of the obscure intermediate deposits which in other localities have been found lying between the base of the Cambrian and the summit of the Archean series.

From the data furnished by Emmons and Hague, and his own observations, King felt himself able to reconstruct with a considerable degree of accuracy the topographical configurations of the Archean surface, and pictured with great clearness the growth of that portion of the American continent included within the area surveyed. He conceived that, at the close of the Archean age, there was a great mountain system built up of at least two sets of nonconformable strata, referred to Laurentian and Huronian, which was coextensive with the greater part of the Cordilleras.[a] This, west of 117° 20′, formed a land area and to the eastward a sea bottom, upon which last, throughout the entire Paleozoic period, were conformably deposited the gradually accumulating detritus from the land, brought down by eastward-flowing rivers. These Paleozoic sediments he found in the region of the Wasatch to be 32,000 feet in thickness, and in the extreme western limit, upward of 40,000 feet.

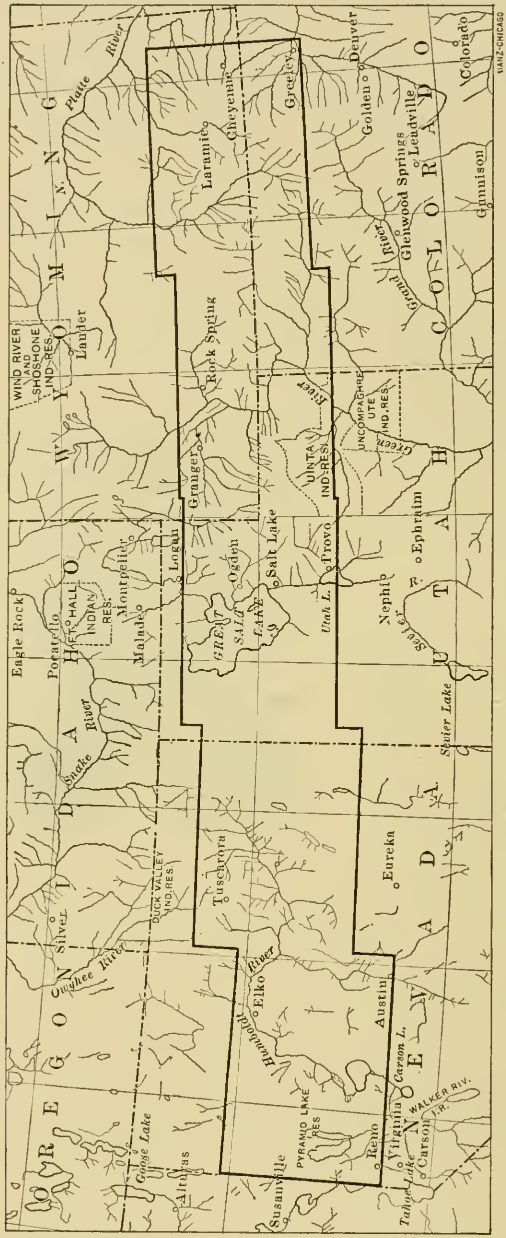


FIG. 111.—Map showing area covered by the Fortieth Parallel Survey.

He divided the series into four great groups: The first, which is purely detrital, being wholly of Cambrian age; the second, a limestone series of 11,000 feet in thickness, extending from the Cambrian to the top of the lower Coal Measures, and indicating a deep-sea deposit. Succeeding this came the Weber quartzite—a purely siliceous deposit of from six to ten thousand feet in thickness—followed by the fourth group of upper Coal Measure limestone, about two thousand feet in thickness. The entire Paleozoic series he summed up as composed of materials of two periods of mechanically

[a] King used the word *Cordilleras* to designate the entire series of mountain chains bordering the Pacific front of North America, limiting the term *Rocky Mountains* to the eastern front only.

accumulated detritus, interrupted by one and followed by another period of deep-sea limestone formation.

At the close of this great conformable period of Paleozoic deposition there were widespread mechanical disturbances. All the thickest part of the sediments, from the western shore line eastward to and including what is now the Wasatch, were raised above the ocean level to become a land area. East of the Wasatch the ocean bottom, with its Upper Carboniferous sediments, remained practically undisturbed.

Contemporaneous with or immediately succeeding this uplift, the old land mass to the westward went down. What was sea bottom had become land, and what was land became sea bottom. But the new land area extending from the Wasatch westward to the Havallah range (long. 117° 30′), under the combined action of heat, cold, and mechanical action of the atmosphere, began at once to yield the materials which, in the form of sand and silt, were carried west and east to be laid down, in the first-named instance on a gradually sinking Archean bottom, until a thickness of 20,000 feet was reached, and in the last named, conformably upon a bottom of Upper Carboniferous rocks, until some 3,800 feet had accumulated.

At the close of this period of sedimentation, which includes the Triassic and Jurassic, the Western ocean with its twenty-odd thousand feet of sediments underwent a sharp folding and uplifting, whereby the shore line was pushed outward as far as the western base of the present Sierra Nevadas. The force causing this uplifting acted tangentially and was most severe in the extreme western portion, i. e., the Sierras, where, in a belt of about 50 miles width, the Triassic and Jurassic sediments were crumpled and crowded together and crushed into a mass of almost undistinguishable folds. During all this powerful disturbance in the Western sea, the region east of the Wasatch remained practically undisturbed, as before.

King's views regarding the geographic distribution of land and water during the subsequent period of geological history were largely in harmony with those of Hayden. During the Cretaceous times he believed a Mediterranean ocean to have stretched from the eastern base of the Wasatch into Kansas. Over the bottom of that body of water an almost continuous conformable sheet of Cretaceous sediments was laid down, the greatest thickness of which was against the western shore of the ocean—that is, along the base of the Wasatch, where were found, conformably over the Jurassic shales, about 12,000 feet of Cretaceous beds.

With the close of the Cretaceous period of sedimentation the entire area from and including the Wasatch, eastward as far as the Mississippi Valley was uplifted, and in its western portion faulted or thrown into sharp or gently undulating folds. The immediate effect of this uplifting was, first, the development of the broad level region now occupied by the Great Plains; secondly, the outlining of the basin of the Vermilion Creek (Wasatch) Eocene lake; thirdly, the formation of the distinct folds of which the Wasatch and Uintas are the most prominent examples; and fourthly, the relative upheaval of the old Archean ranges, with all their superincumbent load. The folds of the Wasatch involved a conformable series of strata extending from the base of the Cambrian to the top of the Cretaceous—in all, 44,000 feet in thickness. The astonishing and almost incredible feature of the case lies in the fact that, if King's ideas are to be accepted, this stupendous fold, together with the one of 30,000 feet forming the Uintas, was not a gradual uplift, but of sudden and necessarily catastrophic origin, and that, before the forces of erosion had accomplished their work, there actually here existed mountain ranges from 5 to 8 miles in height.[a] From the date of this elevation no marine waters have ever invaded the middle Cordilleras, the subsequent strata being, as noted by Hayden, of lacustrine origin.

FIG. 112.—Arnold Hague, Clarence King, Samuel Franklin Emmons.

Studying in detail the underlying geology, in connection with these folds, King announced the principle "that wherever an Archean mountain range underlay the subsequent sheets of sediment, there a true fold has taken place;" and further, that when one observes "the continuity of the strata across such a valley

[a] King's exact words are: So that, since the ocean level was banished to somewhere near its present position, the fold itself (i. e., the Wasatch) was not less than 44,000 feet in altitude. The Uinta was not so imposing a body, but its summit, before erosion began, was certainly 30,000 feet above the sea level. (Systematic Geology, p. 748.)

as that of the Laramie Plains, and then sees them sharply and suddenly rise against the foothills of the Archean, it becomes evident that the entire area of the Rocky Mountains has suffered actual lateral compression, and that the diminution of surface amounts to from 6 to 10 per cent." When he further considered that the post-Archean sedimentaries were to be regarded as a mere thin covering over the subjacent crust, he added that "this diminution of area of actual surface means an actual compression of the solid Archean shell of the earth."

Pursuing the same line of thought, King noted that the configuration of America to-day is due to the configuration or topography of the pre-Cambrian continent. Where Archean faults or mountain chains existed, there were the lines of weakness along which later orographic movements made themselves manifest. A comparatively thin coating of sedimentary beds, for illustration, overlies the generally smooth Archean rocks of the Mississippi Valley, and here no subsequent disturbances have taken place. On the other hand, the high Archean Wasatch ridges, which were covered by 10,000 feet of sediment in post-Archean times, were again and again uplifted during the subsequent periods of disturbance.

It was noted above that, at the close of the post-Cretaceous uplifting, the Wasatch highland stood at an elevation of upwards of 40,000 feet. Under such extraordinary conditions rapid and intense erosion was inevitable, and in a comparatively brief period, geologically, the Vermilion Creek Eocene lake was filled with sediments derived therefrom to a depth of 5,000 feet.

Then ensued another period of disturbance, by which the western portion of these Vermilion Creek beds was upturned, while the region to the immediate west, from which their sediments had been derived, was as suddenly depressed, allowing the waters of the lake to extend themselves 200 miles westward into Nevada.

Another series of crustal movements was now inaugurated in the east, whereby the Great Plains land area also underwent a subsidence, which was most pronounced along the foothills of the Rocky Mountains and gradually died out to the eastward. This movement marks the dividing line between the Eocene and the Miocene periods. Contemporaneously with this the entire Great Basin area, including portions of Washington, Oregon, Nevada, and California, lying to the east of the Sierras and the present Cascade Range, became depressed, and, receiving the drainage of the surrounding hills and mountains, was converted into two large lakes which, throughout the Miocene period, were depositories of sediment from the adjacent land. Powerful and profound crustal movements at the close of the Miocene threw the beds into folds, but did not apparently raise them above the surface level of the lake. Contemporaneously with this movement the

Miocene lake of the east, through the subsidence of the surrounding country, was so increased as to cover almost the entire province of the Great Plains.

The beginning of the Pliocene period found, then, two enormous fresh-water lakes, the one covering the basin country of Utah, Nevada, Idaho, and eastern Oregon, the other occupying the Plains province. The period was brought to an end by crustal movement which, however, affected the two areas quite differently, the sediments of the Great Basin area being broken through the middle and the halves depressed from 1,000 to 2,000 feet, while those of the Plains were bodily tilted toward the south and east.

The result of the post-Pliocene movement in the department of the Plains was to give thereafter a free drainage to the sea. The result in the area of the Great Basin, on the other hand, was to leave two deep depressions, one at the western base of the Wasatch and one at the base of the Sierra Nevada, which in Quaternary times received the abundant waters of the Glacial period and formed the two now nearly extinct lakes known as Lake Lahontan and Lake Bonneville, noted elsewhere.

Sketch of King

King was born at Newport, Rhode Island, in 1842, and graduated from the Sheffield Scientific School in 1862, being a member of the first class to receive degrees from that institution. The year following his graduation he, in company with James T. Gardner, joined an emigrant train starting from St. Joseph, Missouri, on an overland trip to California. It is stated that it was during this trip, at that time a slow and eventful one, that he conceived the idea, afterwards carried into execution, of a geological section across the entire Cordilleran system. Reaching California, he attached himself as a volunteer assistant to the State survey of California, under J. D. Whitney. Later he was connected with parties under General McDowell in the examination of the mineral resources of the Mariposa grant. It was during this expedition that he and his companion were captured by Apaches, but were fortunately rescued just as the fires were being prepared for their torture.

After the civil war and the passage of the bill subsidizing the Pacific Railroad, King recognized that the time had come for carrying out his scheme for connecting the geology of the East with that of the West and making the cross section above referred to. With this project in view he went to Washington in the winter of 1866–67, and in spite of the disadvantage of his youth—being then scarcely 25 years of age, and still more youthful appearance—he was so successful in impressing Congress with the importance of ascertaining the character of the mineral resources of the country about to be opened that not only was a generous annual appropriation voted, but King was him-

CLARENCE KING.

Director of U. S. Geological Explorations of Fortieth Parallel.

self placed in charge, subject only to the administrative control of Gen. A. A. Humphrey, as already mentioned.

The published results of this survey we have already reviewed. As described by Emmons, from whose sketch most of what is here given of the personal history of King is quoted, "probably no more masterly summary of the great truths of geology had been made since the publication of Lyell's Principles." Making due allowance for the enthusiasm of one who was an associate and warm personal friend, attention need only be called to the fact that the entire work was consummated before its author saw his fortieth birthday, to establish once and for all King's fame as an organizer and geologist.

Aside from the publications under this survey, King's bibliography contains few titles, but this may mean simply that neither ink nor words were wasted. In 1877 he delivered an address at the thirty-first anniversary of the Sheffield Scientific School on Catastrophism and the Evolution of Environment, which Emmons characterized as a "protest against the extreme uniformitarianism of that day." It was naturally based largely on his Fortieth Parallel work. This uniformitarianism he described as "the harmless undestructive rate (of geological changes) of to-day prolonged backward into the deep past." He contended that while the old belief in catastrophic changes had properly disappeared, yet geological history, as he read it, showed that the rate of change had not been uniform, as was claimed by the later school. He believed rather, as a result of his own observations, that at certain periods in geological history the rate of change had been accelerated to such a degree that the effect produced upon life was somewhat catastrophic in its nature.

One act in King's professional career should be here referred to, although the story has often been told. It will be remembered that in 1872 there was made a reported discovery of a diamond field in southern Arizona within an area that had been gone over in the course of the work of the Fortieth Parallel Survey. King, for purely scientific purposes, undertook a study of the region, with the purpose of discovering something regarding the matrix and the origin of the diamond. He discovered, rather, that the whole matter was a stupendous fraud; that, so far from there being a diamond mine, the ground had been "salted." So soon as this discovery was made King started for San Francisco, traveling night and day, that he might outstrip all other possible sources of information. On his arrival he at once visited the offices of the directors of the company organized for the selling of stock, and demanded peremptorily that all issues should be stopped. To a suggestion that his announcement of the fraudulent nature of the claim be delayed temporarily, he replied: "There is not money enough in the Bank of California to induce me to delay this announcement a single hour." And it was not delayed.

By those who knew him, King is described as a man of rare charm of manner, cheerful and courteous disposition, with interests broad as civilization and sympathies catholic as humanity. A man of remarkably robust physique, he yet broke down almost in the prime of life, and died of consumption in 1901.

U. S. GEOLOGICAL SURVEYS WEST OF THE 100TH MERIDIAN UNDER LIEUT. G. M. WHEELER.

Wheeler's Surveys West of the 100th Meridian, 1869–1879.

In 1869 Lieut. G. M. Wheeler, of the United States Engineers, was authorized to undertake a military reconnoissance for topographical purposes in southwest Nevada and western Utah. No geologist accompanied the party until 1871, the work being purely topographical. In the last-named year G. K. Gilbert was appointed chief geologist, serving through three field seasons, with A. R. Marvine, assistant in 1871, and E. E. Howell, in 1872–73. J. J. Stevenson served as geologist with one of the parties in 1873, Jules Marcou in 1875, A. R. Conkling in 1875–1877, and J. A. Church in 1877. In 1878–79 Stevenson was again attached to the survey, with I. C. Russell as assistant. Oscar Loew served as mineralogical assistant during 1871–1875, and E. D. Cope as vertebrate paleontologist in 1874.

Fig. 113.—Grove Karl Gilbert.

The invertebrate paleontological collections made by all of the parties were worked up by Dr. C. A. White, then connected with Bowdoin College, after a preliminary examination by F. B. Meek. The results of the geological work appeared in the form of two quarto volumes, the first, of 681 pages, in 1875; and the second, of 420 pages, in 1881—the latter with an appendix by Doctor White, comprising 36 pages of text and 2 plates of fossils. The paleontological report proper, comprising the work of both Cope and White, appeared under date of 1877, a quarto volume of 599 pages and 83 plates of fossils.

The first vertebrate fossils from the western Triassic were described in this report, the materials having been obtained by Professor Newberry when attached to the Macomb expedition in 1855.

Gilbert applied the names Basin Range system and Basin Ranges to all that system of short mountain ridges separated by trough-like valleys which lie west of the plateau system, though not quite coincident with the Great Basin itself. This basis system of mountain uplift he regarded as due mainly to faulting and tilting, in this respect differing with the geologists of the Fortieth Parallel Survey, who regarded the primary features as due to folding, the now evident faulting being a phase of late Tertiary or post-Tertiary time.[a] He noted that the ranges were parallel, recurring at regular intervals and of only moderate dimensions; further, that the ridges of the system occupied loci of upheaval, and were not residua of denudation; and that the valleys were not valleys of erosion, but mere intervals between the lines of maximum uplift.

He dwelt in considerable detail upon the phenomena of erosion by wind-blown sand and silt-laden streams, and discussed the glacial phenomena and the conditions attending the drying up of the great inland lakes, applying the name Lake Bonneville, in honor of Captain Bonneville, the explorer, to the great body of fresh water that once occupied Sevier and Salt Lake valleys and of which the present bodies of salt water bearing these latter names are but the tiny residuals. Those great bodies of water, which obviously could have existed only under conditions of climate quite different from those of to-day, he

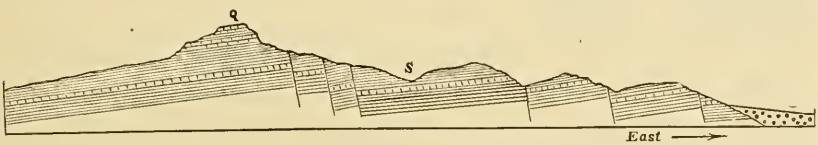


FIG. 114.—Section of the Pahranagat range at Silver Canyon. (After G. K. Gilbert.) Scale, 1–72000. Base line=level of Great Salt Lake. *Q*, Quartz Peak; *S*, Sanders Cañon.

believed to be coeval with the Glacial period of the northeastern States. He found, however, no counterpart in this region of the general glaciation of the eastern States, though there were local glaciers high upon the flanks of the mountains.

The abundant volcanic phenomena presented by the region were discussed in considerable detail and the recency of many of the lava flows noted, the conclusions arrived at being to the effect that while "we are not merely permitted to think of a renewal of that activity as possible * * * we are logically compelled to regard it as probable."

The geological history of the basin region as read by Gilbert was to the effect that the area was depressed below sea level from the close of

[a] In Chapter VII of the volume on Mining Industry (Vol. III, Report, 40th Parallel Survey, 1873) King refers incidentally to these mountains as the tops of folds whose deep synclinal valleys are filled with Tertiary and Quaternary detritus. Just how fully the problem may have been worked out in his own mind at that time is not apparent, but in 1878, after the appearance of Gilbert's monograph, he expressed the opinion noted above. The entire subject, it may be stated, was gone over by J. E. Spurr in a paper read before the Geological Society of America in 1900 (see Bull. Geol. Soc. Amer., XII, pp. 217–270), and the matter rediscussed at the winter meeting of the same society in Washington in 1902. The prevailing opinions there expressed were in accordance with the views put forward by Gilbert in 1875.

the Archean period until late Carboniferous. From the close of the Carboniferous to the beginning of the Cretaceous a great area, including the entire plateau country, was covered by the waters of an inland sea entirely cut off from the main ocean. Only once did the sea regain a temporary sway, bringing with it a Jurassic fauna and then retreating. Throughout the Cretaceous age the plateau country was the scene of a shallow ocean, the shores of which were ever advancing and receding. Through the upraising of some remote barrier the ocean was permanently shut out and the inland sea gradually converted into an immense fresh-water lake, and finally drained till the whole region became terrestrial. Since the expulsion of this sea the elevation of the continent which caused it has continued, and the plateau country, which from early Silurian to late Cretaceous times was slowly sinking to an extent of not less than 8,000 feet, has been bodily uplifted to its former altitude.

Fig. 115.—Edwin Eugene Howell.

Gilbert called attention to the almost entire absence of Upper Silurian and Devonian fossils in the region, and described the volcanic necks or plugs as vestiges of the flues through which the eruptions reached the surface, the last contents congealing in the flue to be subsequently exposed by erosion.

A. R. Marvine, who was attached to the party in 1871 as an astronomical assistant, was later detailed for geological work, his report on the region between Fort Whipple, New Mexico, and Tucson, Arizona, occupying pages 191–225 of the third volume.

E. E. Howell, as a member of the survey during 1872–73, worked throughout the first season in western Utah and eastern Nevada and the plateau region of central Nevada. In 1873 he once more entered the plateau country and continued upon it to Arizona and New Mexico. His report is included in pages 227–300 of the same volume.

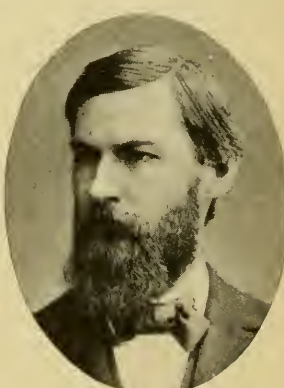


Fig. 116.—John James Stevenson.

The party to which J. J. Stevenson was attached as a geologist was assigned in 1873 to work in southern Colorado, the region including portions of the drainage areas of the South Platte, Arkansas, Rio Grande, San Juan, Grand, and Gunnison rivers.

Stevenson devoted considerable attention to a discussion of the geological age of the Colorado lignites, which he regarded (Lesquereux to the contrary, notwithstanding), as Cretaceous. He agreed with J. L. Le Conte in regarding the Rocky Mountains as not the product of one upheaval, nor the several axes wholly synchronous in origin. The first great epoch of accelerated disturbance in the Rocky Mountain region, resulting in the permanent elevation of the surface, he thought to have been synchronous with that during which the Appalachian chain was completed. Further, that the second epoch of elevation began toward the close of the Triassic. This was followed by a period of subsidence during which the Cretaceous beds were laid down, a third period of uplift marking the close of the Cretaceous. During this latter period volcanic agencies were in a state of intense activity, and a vast sheet of lava, two to three thousand feet in thickness, flowed out over the whole region of the Grand and Gunnison rivers. During the Tertiary period still another elevation took place, sufficient to give the rocks of that age a dip of some 5 degrees.

In his report of the work for 1879 Stevenson discussed in considerable detail the relations of the Laramie group, which he regarded as but the upper part of Hayden's Fox Hill group—that is, of very late Cretaceous age. He felt that there was no doubt but that the coal fields of the Galisteo area and of southern Colorado were of precisely the same age as those of northern Colorado and Wyoming.

THE UNITED STATES GEOLOGICAL AND GEOGRAPHICAL SURVEYS UNDER J. W. POWELL.

J. W. Powell's first observations on the geology of the Uinta Mountains were made in 1869, when engaged in his famous exploration of the Grand Canyon, already noted. In 1871, 1874, and 1875 he again visited the plateau region, the last year being accompanied by Dr. C. A. White. The results of these later years of exploration are given in the quarto monograph on the Geology of the Eastern Portion of the Uinta Mountains, published in 1876. This comprised, all told, 218 pages, with a large folio atlas.

Powell's Geology of the Uinta Mountains, 1874-75.

The expedition of 1875 and those of the intervening years until 1880 were made under the authority of the Department of the Interior, the organization, with Powell as director, being known as the second division of the U. S. Geological and Geographical Survey of the Territories. In 1877 the name was changed to the U. S. Geographical and Geological Survey of the Rocky Mountain Region.

In none of the early Powell surveys was an attempt made at systematic areal work. Certain striking and well-exemplified features were selected and made the subject of special monographs. In the work of 1876, above noted, Powell divided the region west of the Great

Plains, east of the Sierra Nevada, and south of the North Platte, Shoshone, and Sweetwater rivers into what he designated as geological provinces—the Park Province, the Plateau Province, and the Basin Province.

The first named he described as characterized by broad, massive ranges, sometimes distinct and sometimes coalescing, so as to include the great parks. The mountains comprise high, lofty, snow-clad peaks which form perennial reservoirs for the multitude of streams discharging in part into the Colorado River and thence into the Gulf of California, and in part into the Rio Grande and thence into the Gulf of Mexico.

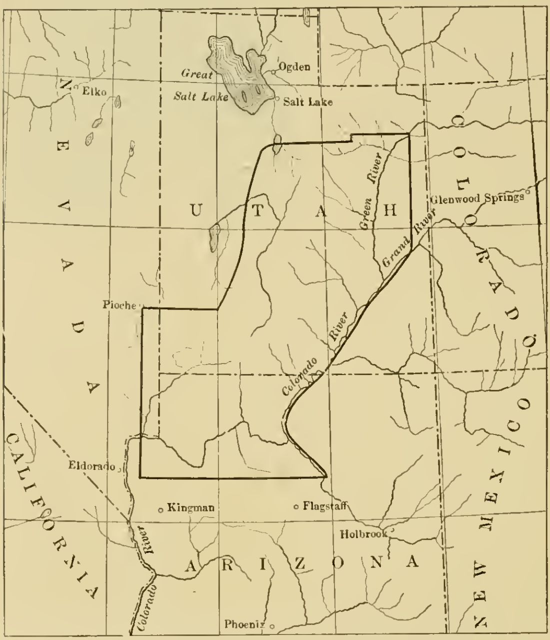


FIG. 117.—Showing area surveyed and mapped by the Powell survey in 1875–80.

The Plateau Province he described as characterized by many tables bounded by canyon and cliff escarpments, and on which stand lone mountains and irregular groups of mountains and short ranges. This region drains almost wholly into the Colorado River.

The Basin Province was characterized by short north-and-south mountain ranges and ridges separated by desert valleys, and with a drainage which is almost wholly into the interior salt lakes and sinks.

Devoting himself mainly to the Uintas, he showed that they owed their present configuration to the degradation of a great upheaved block having its axis in an east-and-west direction. This upheaval, which he thought took place very slowly and gradually, began at the close of Mesozoic time and continued with slight intermissions until late Cenozoic. The total amount of upheaval in the axial region was more than 30,000 feet. Contemporaneously with upheaval the forces of degradation were at work, though not at the same rate of progress, along the axial line of uplift, the degradation amounting to more than 25,000 feet ($4\frac{3}{4}$ miles), and the mean degradation to $3\frac{1}{2}$ miles; so that over the entire area of about 2,000 square miles some 7,100 cubic miles of rock material have been removed.

During the years 1874, 1875, and 1876 Capt. Clarence E. Dutton, of the Ordnance Department, U. S. Army, made, under direction of the Powell survey, further studies in the plateau region which had already received attention from Powell, Newberry, and others, as previously noted. Dutton's monograph—a Report on the Geology of the High Plateaus of Utah, a quarto volume of 307 pages, with an atlas—appeared under date of 1880. The particular territory studied by Dutton lay in Utah, occupying a belt of country extending from a point about 15 miles east of Mount Nebo, in the Wasatch, south-southwest for about 175 miles, and having a breadth of from 25 to 80 miles—a total area of some 9,000 square miles.

Dutton's Work on the High Plateaus, 1874-1876.

As was the case with Powell, as indeed must here be the case with every observing man, Dutton was impressed with the evident signs of the vast amount of erosion which the country had undergone within comparatively recent geological times. Noting that from an area of 10,000 square miles from 6,000 to 10,000 vertical feet of strata have been removed, he fell to speculating on the probable effect upon the earth's equilibrium of such a transference of materials. If the slow accumulation of great masses of sediment on sea bottoms brings about a gradual subsidence, why should not, he argued, the removal of a like load from any land area result in a corresponding uplift or elevation. Thus, for the second time in the history of American geology, was broached the now well-known subject of isostacy. (See p. 499.) This great erosion, it is well to note, he regarded as having taken place mainly in Miocene time, though continuing on into Pliocene.

Fig. 118.—Clarence Edward Dutton.

He noted that the great structural features of the high plateaus were due to faults and monoclinal flexures; also that the one form of displacement passed continually into the other—that what is here a simple fault passed by subdivision, but a few miles farther along in its course, into what he designated as step faults, and still farther on into unbroken anticlinals. All of these grander displacements belonging to the same system he regarded as having their commencement in the latter part of Pliocene times.

The great amount of volcanic activity evident received attention, the most ancient dating back to Eocene times. The character of the volcanic products was studied and the various lavas classified as (1) propylite, (2) andesite, (3) trachyte, (4) rhyolite, and (5) basalt, named here in order of their extrusion. The facts, as a whole, in this region he believed to be confirmatory of Richthofen's law of the sequence of volcanic rocks.[a] He noted his objections to the German method of rock classification based upon geological age.

Gilbert's Work in the Henry Mountains, 1875-1877.

In 1876 G. K. Gilbert, then a member of Major Powell's corps, made a study of the Henry Mountains of Utah. His report appeared in 1877 in the form of a quarto volume of 160 pages, with five folding plates, and numerous plates and figures in the text. In this he showed that these mountains were due to the intrusion from below of igneous matter through Carboniferous and Triassic strata, causing the overlying Cretaceous and Tertiary beds to arch or bulge upward, the present aspect of the mountains having resulted from erosion, whereby the overlying bulged beds and a portion of the igneous rocks as well were cut away. Phenomena of this type had been previously noted by Holmes, Peale, and Marvine, of the Hayden Survey (pp. 601, 602), but it remained for Gilbert to fully elaborate the idea, and that in a manner that must ever connect it with his name. To intrusions of this type he gave the name of laccolites.

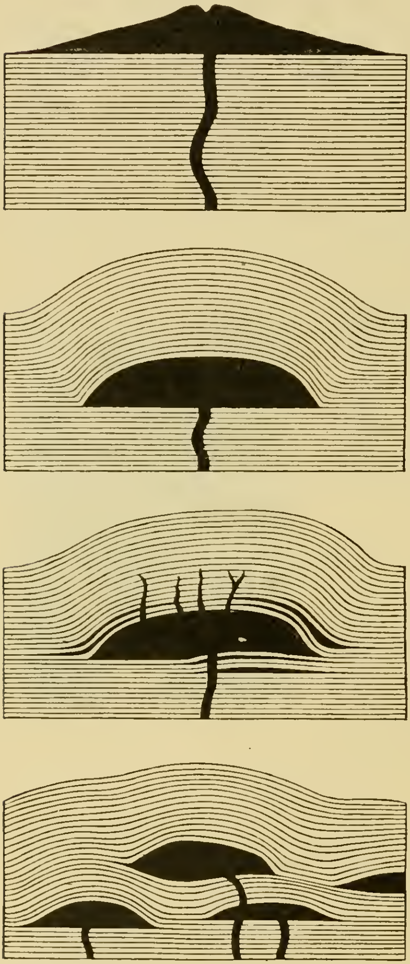


Fig. 119.—Laccolites. (After G. K. Gilbert.)

In this report Gilbert showed that, in the uplifting of the sandstone to form these domes, the beds, as in the case of that of the Vermilion Cliff sandstone, might be elongated as much as 300 feet in a distance of three miles. That this could be done, and that suddenly, he believed to be due to the pressure of the overlying beds. The material was in a quasi plastic condition, and no fissures could be opened unless coincidently filled by some material which would

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[a] Richthofen divided the Tertiary and post-Tertiary volcanic rocks into the five classes given above, and regarded them as having been the product of a regular sequence of eruptions, propylite being the most ancient and basalt the most recent.

JOHN WESLEY POWELL.

Director of U. S. Geographical and Geological Survey of the Rocky Mountain Regions.

resist the tendency of the walls to flow together. This consideration led him to the conclusion that—

just as for each rock there is a crushing weight, so there is for each rock a certain depth at which it can not be fissured.

Applying this principle to faults and fissure veins he concluded that—

if the fault extend to a great depth it will finally reach a region where the hardest rocks which it separates are coerced by so great a pressure that they can not hold themselves asunder, but are forced together before the fissure can be filled by mineral deposits. Thus, there is a definable inferior limit to the region of vein formation.

This the present writer believes to be the first time the doctrine of rock flowage was put forth in America and by an American.

The matters of instability of drainage lines, planation, and formation of river terraces were discussed, and it was shown that Hitchcock's idea of the formation of river terraces by successive periods of sedimentation (p. 462) was erroneous, such in fact being but the recorded stages of progressive erosion. In this work Gilbert used the terms *consequent*, *antecedent*, and *superimposed* as introduced by Powell, and showed that the drainage of the Henry Mountains, while as a whole consequent, was not so in all of its details.

The igneous rocks of the mountains were studied microscopically by Capt. C. E. Dutton, who classed them as trachytes.

Sketch of Powell.

Powell was born of English parentage in Mount Morris, New York, March 24, 1834, and died September 23, 1902. From childhood he manifested a deep interest in all natural phenomena and early gave evidence of that bold and self-reliant spirit which in later years found vent in his hazardous exploration of the Grand Canyon of the Colorado. Vigorous, impetuous, and sometimes intolerant of the opinions of others, he made warm friends and strong enemies. Rising from obscurity, without university training, indeed almost wholly self-taught, to become a bold and aggressive thinker, and finally the head of the U. S. Geological Survey in 1881, it is little to be wondered at that he became for many a target for sneers as well as an object of envy. But however much men may differ as to the value of his individual work in the geological as well as ethnological field, no one will for a moment question that it was through his efforts that others were given the opportunity to carve out their own immortality. Upon his success as an administrator his fame may safely rest.

After his retirement from the Survey in 1894 Powell limited himself mainly to abstruse psychological problems and the directorship of the Bureau of American Ethnology, which, it should be said, he had been largely instrumental in founding in 1880.

Powell served with gallantry during the civil war, rising to the rank of major of artillery. He lost his right arm at the battle of Pittsburg Landing.

As early as 1874 the question of the advisability of consolidating the various geological and geographical surveys west of the Mississippi was considered by a committee of the public lands, to which Congress had referred a message of the President of the United States relating to the matter. The committee made exhaustive investigations, receiving testimony from many interested parties, and undoubtedly a strong effort was made to have the surveys conducted under the direction of the United States Army. In opposition to this was successfully arrayed almost the unanimous opinion of the scientific and professional men of the country. In 1878 the matter was again brought up, with the result of consolidating all of the various surveys under the U. S. Geological Survey, of which Clarence King was appointed director in 1879. Mr. King, however, held the office but a single year, resigning in favor of Maj. J. W. Powell.

Consolidation of all the Geological Surveys, 1879.

FIG. 120.—Packing flour.

THE MOODY FOOTMARK QUARRY, SOUTH HADLEY, MASSACHUSETTS.

CHAPTER VIII.

THE FOSSIL FOOTPRINTS OF THE CONNECTICUT VALLEY.

In the American Journal of Science for 1836 Prof. Edward Hitchcock described a series of fossil footprints occurring in the sandstone of the Connecticut Valley, attention to which had been called by Dr. James Deane, of Greenfield, the latter's notice having been first directed to them by a Mr. Dexter Marsh, of Deerfield, who found them among some flagstones being laid in front of his house. Deane, who was a practicing physician, was quick to realize their geological interest and apparently also recognized his own inability to do the matter justice, and so referred them to Doctor Hitchcock.

Those first found were from a quarry in Montague; later finds were made at the so-called Lily Pond quarry at Turners Falls, a quarry which has yielded in the past and still occasionally yields the finest examples yet produced. Hitchcock described and figured tracks which he regarded as having been made by as many as seven different species of animals. His conclusions regarding their origin were, first, that they were all the impressions of biped animals; second, that they could not have been made by any known biped except birds, and third that they well corresponded with the tracks of birds in having the same ternary division of the feet, with frequently, and perhaps always, the toes terminated with claws, as do birds. To these supposed bird tracks he gave the name *Ornithichnites* (from *ορνίς* and *τίχνοσ*), signifying stony bird tracks. Five years of further examination enabled him to swell the list of species to 27, which were described and figured, natural size, in his final report on the geology of Massachusetts, 1841.

Up to this last date he had found no certain evidence that any of the tracks were made by quadrupeds, yet a considerable proportion of them bore so strong a resemblance to saurian reptiles that he denominated them *sauroidichnites*, or tracks resembling those of saurians, intending, however, by the term merely to convey an intimation that they might prove reptilian. To the others he now applied the name *ornithoidichnites*, or tracks resembling those of birds. To animal tracks of all kinds, and of whatever nature he proposed the general name *ichnolites*.

At the April meeting, 1842, of the American Association of Geologists, Hitchcock brought the matter up once more, describing five new species, one of which, *O. tuberosa*, from Pompton, New Jersey, was the first thus far found outside of the Connecticut Valley.

In this same paper he also announced the finding of tracks which afforded the first "certain evidence that any of the numerous tracks

Fig. 121.—Fossil foot prints (After Edward Hitchcock.)

upon the sandstone of the Connecticut Valley were made by a quadruped," though he had suspected that such might be the case. These probable quadrupedal tracks he described under the name *Sauroidich-*

nites deweyi, and it was suggested that they were comparable with the *Cheirotherium*, an amphibian found in the European Keuper beds (Triassic). This discovery, naturally, raised again the question as to the possible quadrupedal nature of the others described, but, with characteristic conservatism, he still refrained from committing himself, simply noting that it would be "contrary to the cautious spirit of science" to decide on the evidence then at hand as to their exact nature, and he therefore adhered to the course adopted in his previous report, and classified all under the names as *ornithoidichnites* and *sauroidichnites*, as before.

It is scarcely necessary to remark that the discovery of these tracks excited a very lively interest both at home and abroad, and references and suggestions regarding them multiplied in the geological literature of the day. Thus, in the American Journal of Science, XLV, 1843, under the title of Ornithichnites of the Connecticut River Sandstones and the Dinornis of New Zealand, we find given the opinions of Deane, Hitchcock, Mantell, and Richard Owen regarding their nature. Deane, in a letter to Doctor Mantell, of London, had written:

> These beautiful fossils, indicating a high grade of animal existence in a period of the earth so immensely remote, may well be regarded among the wonders of paleontological science. * * * That the footsteps of the Connecticut River are, however, the authentic traces of extinct birds is confirmed by the undeviating comparisons they bear to living nature.

He wrote further of referring these footprints, as discovered by himself, to Professors Silliman and Hitchcock, both of whom admitted the plausibility of his statements, yet remained incredulous as to the inferences drawn until accurate models were submitted to them, when Professor Hitchcock had pronounced his unqualified conviction that the footprints were those of birds. Doctor Mantell in his reply to Doctor Deane seems to have himself accepted the opinion of their bird-like nature, and stated further that at first both Professors Owen and Murchison were in doubt as to whether they were made by birds or reptiles. Mr. Lyell, however, stated his conviction that they were genuine *ornithichnites*. Later, Professor Murchison, after considering the enormous size of the tracks which must have been made by the New Zealand moas, "confessed that the gigantic bones from New Zealand, evincing as they did most unequivocally the existence even in our own times of birds as large as any required by the American footmarks, had removed his skepticism, and that he had no hesitation in declaring his belief that the *ornithichnites* had been produced by the imprints of the feet of birds which had walked over the rocks when in a soft and impressible state." "An opinion," adds Mantell, "in which I entirely concur."

Dr. Richard Owen, too, in a letter to Professor Silliman, under date of March 16, 1843, after calling attention to the need of caution in assuming the existence of highly organized birds at so early a period, particularly when there were known to be large reptiles which might make tracks very similar, went on to speak of the then recently described Dinornis[a] of New Zealand, and wrote as follows:

It seems most reasonable, therefore, to conclude that the *ornithichnites* are the impressions of feet of birds which had the same low grade of organization as the Apteryx and Dinornis of New Zealand, and this latter may be regarded as the last remnants of an apterous race of birds which seems to have flourished in the epoch of the New Red sandstone of Connecticut and Massachusetts.

The concluding paragraph in the article from which these abstracts have been made is interesting as showing the unqualified acceptation by Murchison of the opinions by the various authorities. Thus, he is quoted as having said:

From this moment, then, I am prepared to admit the value of the reasoning of Doctor Hitchcock and of the original discoverer, Dr. James Deane, who, it appears by the clear and modest paper laid before us (by Doctor Mantell), was the first person to call the attention of the professor to the phenomenon, expressing then his own belief, from what he saw in existing nature, that the footprints were made by birds. Let us now hope, therefore, that the last vestiges of doubt may be removed by the discovery of the bones of some fossil Dinornis. In the meantime let us honor the great moral courage of Professor Hitchcock in throwing down his opinions before an incredulous public.

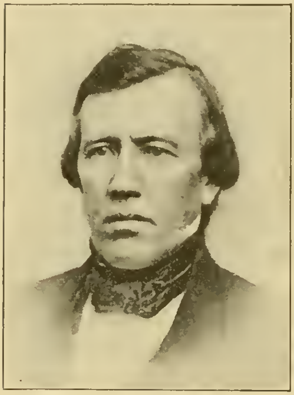

FIG. 122.—James Deane.

About this time Doctor Deane, evidently becoming dissatisfied with the position he was likely to occupy in the discussion, began to himself publish descriptions, his first paper appearing in the American Journal of Science, XLVI, 1844, where he figured a slab some 6 by 8 feet in dimensions containing over 75 impressions. He did not, however, attempt any scientific description of the same, and referred to them as *Ornithichnites fulicoides*, of Hitchcock.

In a paper read before the American Association of Geologists and Naturalists at Washington in May, 1844, Doctor Hitchcock took the subject up once more and gave a brief history of the discovery of footprints in other countries, and also certain data regarding an earlier discovery than that of Doctor Deane, referring to the fact that in 1802 Mr. Pliny Moody, of South Hadley, in Massachusetts, had turned up with the plow upon his father's farm in that place a stone containing in relief five tracks of what he, Hitchcock, now referred to as *Ornith-*

[a] Bones of the Dinornis, the giant bird of New Zealand, it should be mentioned, first came to the notice of the scientific world through the publications of Richard Owen, the English anatomist, in 1839–1843.

ichnites fulicoides. This same slab served for several years the purpose of a doorstep, and finally passed into the possession of Doctor Hitchcock in 1839.

An evident feeling of jealousy between the two gentlemen most concerned is for the first time manifested in this paper, a feeling which apparently existed until the time of Doctor Deane's death, and which caused his friends to publish in 1861 the volume entitled Ichnographs of the Sandstone of Connecticut River, a quarto volume of 61 pages of text and 46 full-page plates.

Hitchcock covered the entire subject up to the date of his reading this paper (1844), and described the fine large specimen found in the impure limestone of Chicopee Falls, in Springfield, under the name of *Ornithoidichnites redfieldii*, and also several other new species. The resemblance of these to saurian remains was still recognized, but the proof was not regarded as sufficient to refer them unequivocally to quadrupeds.

In this paper Hitchcock adopted the following classification for tracks or markings of various kinds:

Order 1. *Polypodichnites*, or many-footed tracks.
Order 2. *Tetrapodichnites*, or four-footed tracks.
Order 3. *Dipodichnites*, or two-footed tracks.
Order 4. *Apodichnites*, or footless tracks.

Under the latter term he included certain marks made by fishes, mollusks, and annelid worms.

In the American Journal of Science for 1845, Doctor Deane had two papers descriptive of footprints found by him and a part of which he thought to be undoubtedly those of batrachians, agreeing in this respect with Hitchcock, as noted above. In his second paper he described and figured tracks made by a batrachian reptile, the method of progression of which, as indicated by the tracks, was by kangaroo-like jumps, the fore limbs not touching the ground. Again, in 1847, Deane had a paper dealing not merely with the tracks, but also with the supposed conditions under which they were formed, the tracks described being in part those of birds and in part those of quadrupeds. Their preservation he regarded as due to the resubmergence during seasons of flood of the mud flats upon which they were formed.

Through the same medium and this same year Hitchcock reverted once more to the subject and described two new species of thick-toed bipeds, the one renamed *Brontozoum* (from *Ornithoidichnites*) *sillimanium*, and the other *B. parallelum*. In connection with these he described a large and extraordinary track regarded as that of a batrachian and to which he gave the generic name *Otozoum*. He regarded the tracks as having been preserved by being silted in by the waves of spring tides.

Again, in 1848, Doctor Deane came forward with a brief paper and figures of tracks which he thought might with propriety be referred to some member of the tailed or salamandrian family of batrachians, since he discovered markings which seemed to him as probably due to the trailing of the caudal appendage. In this same year Dexter Marsh, the man who first called Doctor Deane's attention to the footprints in 1836, in a long letter to the editor of Silliman's Journal, described and figured footprints which he regarded as those of a quadruped and one that walked step by step and not by leaps.

Previous to the forties Hitchcock had given names only to the tracks, but in 1845, acting under the suggestion made to him by Doctor Deane, he presented, at the meeting of the Association of American Geologists, a catalogue of the animals themselves, so far as known, a plan to which he adhered and defended in his paper in the Memoirs of the American Academy of Arts and Sciences, presented in 1848. In this paper he discussed with his usual caution the possibilities of identification and classification from footprints alone, and while he acknowledged that he had no great confidence in the arrangement adopted except in a few instances, went on to submit the following list of genera:

1. *Brontozoum.*
2. *Æthiopus.*
3. *Steropezoum.*
4. *Argozoum.*
5. *Platypterna.*
6. *Ornithopus.*
7. *Polemarchus.*
8. *Plectropus.*
9. *Triænopus.*
10. *Harpedactylus.*
11. *Typopus.*
12. *Otozoum.*
13. *Palamopus.*
14. *Thenaropus.*
15. *Anomœpus.*
16. *Anisopus.*
17. *Hoplichnus.*
18. *Macropterna.*
19. *Xiphopeza.*
20. *Ancyropus.*
21. *Heleura.*
22. *Herpystezoum.*
23. *Harpagopus.*

Under these names he described 49 species, of which he regarded 12 as certainly quadrupeds: 4 probably lizards, 2 chelonians or turtles, and 6 batrachians. Two were annelids or mollusks; 3 of doubtful character; and the remaining 32 species were bipeds. Eight of these 32 he regarded as being thick-toed tridactylous birds; 14 others were probably narrow-toed tridactylous or tetradactylous birds; 2 were perhaps bipedal batrachians, and the remaining 8 he thought might have been birds, but would more probably turn out to be either lizards or batrachians.

It may be noted, in this connection that, in 1845, Dr. Alton King found fossil footprints in Carboniferous sandstone in Westmoreland County, Pennsylvania. These, though now known to have been tracks of amphibians, were described by King under the names of *Ornithichnites gallinuloides* and *O. culbertsoni*, King accepting their birdlike origin, though assuring the reader that the "popular error that these are the tracks of wild turkeys needs no discussion." Certain other tracks

Fig 1

Fig 2

THE APPLETON CABINET.

found at the same time were recognized as those of quadrupeds, and were described under the generic name of *Spheropezium*.

In the Memoirs of the American Academy of Arts and Sciences for 1849, Deane had again a paper on fossil footprints of the Connecticut Valley, which he regarded as in part those of birds and in part those of reptiles. These were described and figured, but no attempt at classification was made.

In 1858 Hitchcock published his Ichnology of New England, a quarto volume of some 200 pages, with 60 plates of footprints and a map of the Connecticut Valley, showing the distribution of the Triassic sandstone with its included tracks, together with a section across the valley at Springfield. This work is of importance, not merely on account of the detailed description of the tracks, but also as summing up the knowledge of the subject and the prevailing opinion regarding the origin and age of the sandstone itself. The sandstone, it should be stated, had been regarded by many geologists as owing its present dip to its having been deposited upon a sloping floor. To this view Hitchcock now took exception and could find no way of escaping from the opinion that it had been upheaved since its deposition. The age of the sandstone he considered to be undoubtedly Jurassic. He discussed in great detail the character of the tracks, and announced some thirty characteristics which he regarded as based on the principles of comparative anatomy and zoology, and which he thought afforded him reliable grounds from which to judge of the nature of an animal from its tracks. He felt that he could now decide with a good degree of confidence, first, whether the animal making the track was vertebral or invertebral; second, whether a biped, quadruped, or multiped; third, to which of the four great classes of vertebrates it belonged and, with less certainty, to what order, genus, or species the animal might be referred. It was in this work that he first proposed the term *Lithichnozoa* (the stony-track animals), to embrace the animals whose characters he described from their tracks. The classification adopted divided the animals into ten groups: First, *marsupialoid* animals; second, *pachydactylous*, or thick-toed birds; third, *leptodactylous*, or narrow-toed birds; fourth, *ornithoid* lizards or batrachians; fifth, *lizards;* sixth, *batrachians;* seventh, *chelonians;* eighth, *fishes;* ninth, *crustaceans*, *myriapods*, and *insects;* and tenth, *annelidans*.

It will be noted that the Brontozoum was still included under the group of pachydactylous or thick-toed birds.

In 1863 we find Hitchcock again returning to the subject in a brief paper in the American Journal of Science for that year, in which he announced that, though having been compelled to give up ten or a dozen of his old species of footmarks, he had described over thirty new ones. Further, finding that an error had been made as to the number of phalanges in the tracks of some of the animals classed as *Lithichnozoa*, he confessed to a doubt if the animals heretofore grouped under this name should be classed as birds; and, as a general conclusion, announced that in fossil footmarks birds could not be distinguished from quadrupeds by the number of phalanges. In this same paper he announced the finding of tracks which were accompanied by certain markings which were evidently made by the tail of the animal, such being particularly characteristic of his *Anisopus gracilis*, an animal the quadrupedal nature of which had already been recognized. The presence of such tail-like markings in the case of the *Anomœpus* lead him into a somewhat lengthy discussion as to the affinities of this animal, whether bird or reptile, though he was evidently inclined to regard it as most nearly related to a lower order of birds like the *Archæopteryx*. In support of this, he appended a letter from Professor Dana, in which he referred to the generalized characters of the early birds.

Fig. 123.—Skeleton of *Anchisaurus colurus* Marsh.

Here the matter would appear to have rested until Mr. Roswell Field, a farmer of Greenfield, Massachusetts, on whose property the first slabs were found, for the first time in print voiced his own opinions. In the American Journal of Science, XXIX, 1860, he gave briefly and modestly the results of his experience in collecting and observing, and announced it as his opinion that the vertebral tracks should all be classed as reptilian. That the animals that made them usually walked on two feet he admitted, but contended that they could as well have walked on four had they chosen. In proof of this he added:

> We find tracks as perfect as if made in plaster or wax which, to all appearances, as to the number of toes and the phalangial or lateral expansions in the toes, agree perfectly well with those of living birds, and still we know, by the impressions made by their forward feet, that these fossil tracks were made by quadrupeds.

In still other cases he noted traces of the tails tracking in the mud. Enumerating some of the cases in which the so-called bird tracks—as, for instance, the *Otozoum*, had been proven to be reptilian—he added that this he verily believed is the place for them all. And in this he was right, but it was not until 1893 that the actual bones of one of the reptiles were found in a sufficiently good state of preservation to allow Prof. O. C. Marsh to make the restoration shown in fig. 123. This particular form was about six feet in height, when standing, as in the figure. "One of the most slender and delicate dinosaurs yet discovered, being only surpassed in this respect by some of the smaller, bird-like forms of the Jurassic." The creature is shown in the figure in the position it is thought to have habitually assumed. On a firm but moist beach only three-toed impressions would have been left by the hind feet and the tail would have been kept free from the ground. On a soft muddy shore the claw of the fifth digit would have also left its mark, and perhaps the tail would have dragged. When, perhaps momentarily, he rested on his fore feet, tracks of a quite dissimilar nature would have resulted, such as at first were assumed to be those of an animal of another species.

And so the matter rests.

Dr. James Deane was born at Coleraine, Massachusetts, February 24, 1801, and became by profession a physician, practicing at Greenfield, in the same State. Eminently successful in his practice, he nevertheless found time for study and work in other lines. "Not a moment was lost that he could spare from the great labors of his profession. Late into the night was his lamp seen glittering from his casement * * * while he was copying, with his masterly touch, these relics of an ancient era" (Bowditch). He is described as a man of few words, though of a genial and social character; of a tall and commanding form, and a well knit, compact frame; a man whose very walk conveyed an idea of strength.

Sketch of Doctor Deane.

SIR WILLIAM LOGAN.

Director of the Geological Survey of Canada.

CHAPTER IX.

THE EOZOON QUESTION.

In his work on the geology of Canada, 1863, Logan described somewhat briefly certain forms strongly resembling fossils which were discovered some three years earlier in the Laurentian rocks belonging to the Grand Calumet series of Canada.

The specimens represented parallel or concentric layers of crystalline pyroxene, the interstices of which were filled with crystalline carbonate of lime, resembling somewhat the structure of the fossil *Stromatopora rugosa* found in the Bird's-eye and Black River limestone. (See fig. 124.) Logan realized the fact that organic remains found entombed in these limestones would, if they retained their calcareous nature, be almost certainly obliterated by crystallization, and it would only be through the replacement of the original lime carbonate by some different mineral substance that there would be any chance of the forms being preserved. Nevertheless, their resemblance to fossil remains was so great that, had the specimens been obtained from the altered rocks of the Lower Silurian series instead of the Laurentian, he thought there would have been little hesitancy in pronouncing them to be true fossils.

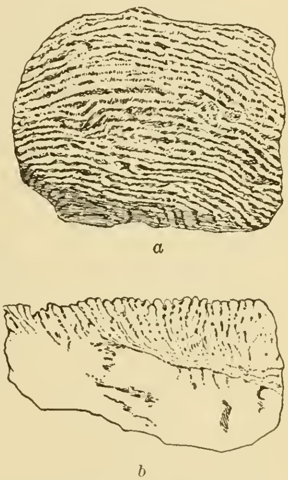

FIG. 124.—Supposed fossil from Laurentian limestone. *a*, Weathered surface; *b*, vertical transverse section (reduced about one-half).

In the Quarterly Journal of the Geological Society of London for 1865 Logan returned to the subject, bringing much new evidence to bear. He described the oldest rocks in North America as those composing the Laurentide Mountains of Canada and the Adirondacks of New York, dividing them into the Lower and Upper Laurentian series, the united thickness of which was estimated to probably exceed 30,000 feet, and this overlaid by a third group (the Huronian), which had been estimated to be some 18,000 feet in thickness. In both the Upper and Lower Laurentian series he found zones of limestone which had sufficient volume to constitute an independent formation.

While studying these rocks he had naturally fallen to speculating upon the possible occurrence of life during the period in which they were being laid down, and his mind was doubtless in a mood to readily accept any promising discoveries. He recognized the fact that the mere apparent absence of fossils from the crystalline limestone did not seem to offer any proof in negation, since such might have been obliterated by metamorphic action, and he referred to the arguments of T. Sterry Hunt in favor of the possible organic origin of the beds of iron ore and metallic sulphurets in the older rocks. When, therefore, these imitative forms were brought to his attention, he candidly acknowledged himself as being disposed to look upon them as fossils, and, indeed, he exhibited them as such at the meeting of the American Association for the Advancement of Science at Springfield in 1859.

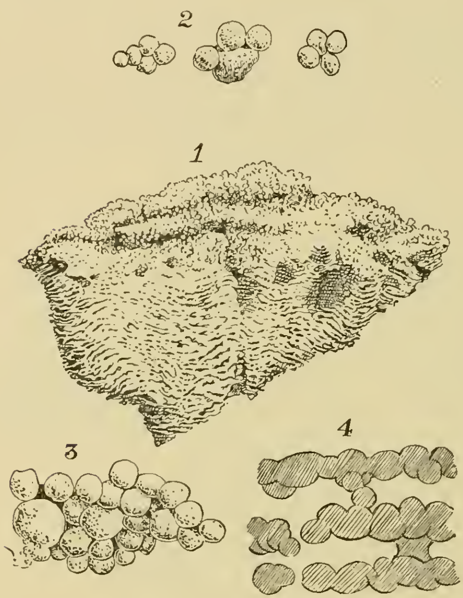

Fig. 125 (Nos. 1 to 4).—Small weathered specimens of *Eozoon canadense*. From Petite Nation. 1, Natural size, showing general form and acervuline portion above and laminated portion below; 2, enlarged casts of cells from upper part; 3, enlarged casts of cells from the lower part of the acervuline portion; 4, enlarged casts of sarcode layers from the laminated part. (After J. W. Dawson.)

Subsequently[a] thin sections prepared from these were referred to Dr. J. W. Dawson, of Montreal, who was regarded as the most practiced observer with the microscope. To Doctor Dawson, then, may be given a large share of whatever credit is due for the recognition of the supposed animal nature of this much disputed body.

The specimens first examined by Dawson were from the base of the so-called Grenville limestone, belonging to the highest zones of the Laurentian, the mass of the rock being composed of great and small irregular aggregates of white crystalline pyroxene, interspersed with a multitude of small spaces, consisting mainly of carbonate of lime, many of which showed minute structures similar to that of the supposed fossil. The general character of the rock he thought conveyed the impression that it was a great foraminiferal reef in which the pyroxenic masses represented a more ancient portion, which, having died, had become much broken up and worn into cavities and deep recesses, affording a seat for a new growth of foraminifera, represented by the calcareous and serpentin-

[a] Quarterly Journal of the Geological Society of London, XXI, 1865, pp. 45–69.

ous part. This in turn became again broken, leaving in some places uninjured portions of the general form.

The main difference between this foraminiferal reef and more recent coral reefs, he thought to be, that, while with the latter there are usually associated many shells and other organic remains, in the more ancient one the only remains yet found were those of the animal which built the reef.

Dawson attacked the problem from the zoologist's standpoint. To properly understand his position and also that of those who combated his arguments, it must be remembered that the science of micro-petrography was then in its infancy; in fact the possibilities of metasomatosis or alteration by indefinite substitution and replacement were only beginning to be realized by even the most advanced of mineralogists and geologists. Hence it was possible for two men, attacking the same problem from opposite standpoints—the one as a chemist and physicist and the other as a zoologist—to arrive at conclusions diametrically opposed to each other.

Fig. 126.—Magnified group of canals in supplemental skeleton of Eozoon. Taken from the specimen in which they were first recognized (Life's Dawn on Earth). (After J. W. Dawson.)

The specimens examined, as already indicated, were masses often several inches in diameter, presenting to the naked eye alternate laminæ of serpentine, or pyroxene, and carbonate of lime, their general aspect reminding one, as already noted, of the Silurian Hydroids of the genus Stromatopora (see fig. 124). Under the microscope Dawson found the laminæ of serpentine and pyroxene to present no organic structure, the pyroxene being highly crystalline. The laminæ of carbonate of lime, on the other hand, he thought retained distinct traces of structure which could be considered only as organic, constituting parallel or concentric partitions of variable thickness inclosing flattened spaces or chambers, frequently crossed by transverse plates or septa. The laminæ themselves were frequently excavated on their sides into rounded pits, and in some places traversed by canals and penetrated by numerous minute tubuli, a structure which can be best understood by a reference to fig. 126.

According to the conclusions of Dawson, the calcareous portion represented the portion of the original shell, the serpentinous matter, on the other hand, being material infiltrated into the cavities which had been occupied by sarcode during the life of the animal. He referred the supposed organism to the group of Rhyzopods of the order of foraminifera, and conceived that during life they were sessile by a broad base and "grew by the addition of successive layers of chambers separated by calcareous laminæ but communicating with each other by canals or septal orifices sparsely and irregularly distributed." He imagined, further, that the organisms grew in groups which ultimately coalesced and formed large masses penetrated by deep, irregular canals and that they continued to grow at the surface while the lower parts became dead and filled up with the infiltrated matter or sediment, assuming the aspect of a coral reef.

On account of their geological position, he proposed to designate the animals by the name of *Eozoon*, and these particular ones by the specific name of *canadense*, and in his annual address before the Natural History Society of Canada for that year, referred to the dis-

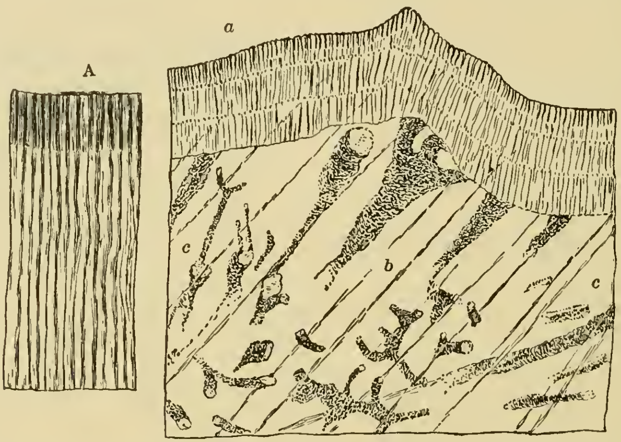

FIG. 127.—Portion of Eozoon magnified 100 diameters, showing the original cell-wall with tubulation and the supplemental skeleton with canals. *a*, Original tubulated wall or "Nummuline layer;" more magnified in Fig. A; *b c*, intermediate skeleton with canals. (After W. B. Carpenter.)

covery as "one of the brightest gems in the scientific crown of the Geological Survey of Canada."

The paper by Dawson was immediately followed by one by the well-known microscopist, W. B. Carpenter, whose conclusions were in every way confirmatory of those of Dawson. To quote his own words:

That the Eozoon finds its proper place in the foraminiferal series, I conceive to be conclusively proved by its accordance with the great types of that series in all the essential characters of organization, namely, the structure of the shell forming the proper wall of the chambers, in which it agrees precisely with Nummulina and its allies; the presence of an intermediate skeleton and an elaborate canal system, the disposition of which reminds us most of *Calcarina;* a mode of communication of the chambers when they are most completely separated, which has its exact parallel in *Cyclocypeus;* and an ordinary want of completeness of separation between the chambers, corresponding with that which is characteristic of *Carpentaria.*

The chemical and mineralogical side of the problem was taken up by T. Sterry Hunt, who found that the silicate portion, i. e., the material filling the chambers, was composed of serpentine or pyroxene in some of its forms.

It is not surprising that the finding of supposed fossil remains in rocks so old as those of the Laurentian should have excited the widest attention, and it would have been strange indeed had such conclusions been allowed to go unchallenged. In 1866[a] there was read before the same society a detailed account of the investigations made by Profs. William King and T. H. Rowney, of Queen's University in Ireland. These gentlemen, although claiming to have had no misgivings at the commencement of their investigations as to the Eozoonal origin of the material, nevertheless attacked the problem from the physical and chemical rather than the biological standpoint. They examined in great detail all of the structures described by Dawson, though not having access to all his materials. Their conclusions were to the effect that (1) the so-called chamber casts or granules of serpentine were more or less simulated by minerals like chondrodite, coccolite, pargasite, etc.; (2) that the "intermediate skeleton" was closely represented both in chemical composition and other conditions by the matrix of these minerals; (3) that the proper wall of Dawson was structurally identical with an asbestic-form layer which was frequently found investing the grains of chondrodite, and that instead of belonging to the skeleton it was altogether independent of that part and formed an integral portion of the serpentine constituting a chamber cast; (4) that the canal system was analogous to the embedded crystallizations of native silver and other similarly conditioned minerals; and (5) that the type examples of casts of stolon passages were isolated crystals apparently of pyrosclerite. From these considerations and the perhaps even more important one that the Eozoonal structure was found only in metamorphic rocks and never in unaltered sedimentary deposits, they concluded that every one of the specialties which had been diagnosed for the *Eozoon canadense* was of purely crystalline origin.

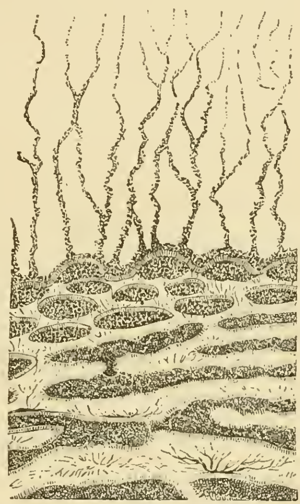

FIG. 128.—Magnified and restored section of a portion of Eozoon canadense. The shaded portions show the animal matter of the chambers, tubuli, canals, and pseudopodia; the unshaded portions the calcareous skeleton. (After J. W. Dawson.)

Such conclusions naturally brought forth prompt rejoinders from Carpenter and others, the controversy becoming in some cases per-

[a] Quarterly Journal of the Geological Society of London, XXII, 1866, p. 185.

sonal and often not particularly creditable to those most interested. Thus Carpenter accused Rowney of never having seen any transparent sections of Eozoon thin enough to give a good view of its tubuliferous layer until he himself had shown it to him; and, further than that, that he had no practical knowledge of the structure of nummuline shells at best. His paper in reply to the statements of Rowney concluded with the remark that he had recently had his attention called to an occurrence of Eozoon, which was preserved simply in carbonate of lime without any serpentine or other foreign mineral, and showing the canal system very perfectly. This he felt was a conclusive answer to King and Rowney's objection No. 3, to the effect that the canal system of Eozoon was no other than crystallization of metaxite, an allomorphic variety of serpentine.

In this same year Ferdinand von Hochstetter found in the crystalline Azoic limestone of Krumman, Bavaria, structures which, when examined by Carpenter, were pronounced by him to be unmistakably those of Eozoon.

The forms thus far found were limited to the Laurentian rocks, and were regarded by both Logan and Dawson as important "horizon markers," i. e., as affording presumptive evidence in favor of the Laurentian age of all rocks in which they might occur. The announcement by C. W. Gümbel of finding Eozoonal structures in the Hercynian gneisses of Bavaria, regarded by him as of Huronian or Cambrian age, was, therefore, both disconcerting and encouraging to the Eozoonists. Gümbel himself adopted enthusiastically the conclusions of Carpenter and Dawson as to the organic nature of the forms. "This discovery," he wrote, "at once overturns the notions hitherto commonly entertained with regard to the origin of the stratified primary limestones. In this discovery we hail with joy the dawn of a new epoch."

In 1867 Sir William Logan again brought the matter to the attention of the Geological Society of London, submitting a specimen of Eozoon obtained in the township of Tudor, Hastings County, Canada, in which the serpentine minerals were quite lacking, it being, in fact, the specimen above referred to by Carpenter. This was examined and described by Dawson, who thought to be able to detect all the essential characteristics of the true Eozoon. In presenting his description of this new find, Dawson took occasion once more to challenge the work of Messrs. King and Rowney, and accused them of making the fundamental error of defective observation in failure to distinguish between organic and crystalline forms, an accusation which he substantiated (?) by a long argument not necessary to reproduce here.

From this time on, literature on both sides of the Atlantic contains many references and matter more or less relevant to the discussion. By many of the best informed the organic nature of the fossil was considered to be an open question, and but few American geologists, so far as I am aware, ever openly advocated it.

In 1871 Messrs. King and Rowney read before the Royal Irish Academy a paper on the geological age and structure of the serpentine marble of Skye, in which reference was made to structures closely simulating those of the Eozoon, the rock in this case being of Liassic age, and the imitative forms being the result of structural and chemical changes to which such siliceous minerals as malacolite and other varieties of lime magnesian pyroxenes were characteristically liable.

This paper was followed the same year by another on the mineral origin of the so-called *Eozoon canadense*, which passed in review all of the accumulated evidence both for and against, reiterating and emphasizing many of the statements made in previous papers. They held that the so-called intermediate skeleton and the chamber casts of the Eozoon were completely paralleled in various crystalline rocks containing pyroxene, the chamber casts being, in fact, composed occasionally of loganite and malacolite besides serpentine, a fact which, instead of favoring the organic origin, as claimed, was to be held as proof of their having been produced by mineral agencies.

With reference to Gümbel's observations regarding the rounded cylindrical or tuberculated grains of coccolite and pargasite which he found in various crystalline marbles and supposed to be chamber casts, they claimed to have found upon such grains crystalline planes, angles, and edges, "a fact clearly proving that they were originally simple or compound crystals that have undergone external decrètion by chemical or solvent action."

The so-called nummulitic layer they contended had originated directly from closely packed fibrous or asbestiform serpentine, and that it occurred in cracks or fissures in both the Canadian and Connemara (Ireland) ophite. The fact that the two superposed asbestiform layers forming the upper and under proper wall and their component aciculi often passed continuously and without interruption from one chamber cast to another, they argued was totally incompatible with the idea of this nummuline layer having resulted from pseudopodial tubulation. The canal system they found to be composed of serpentine or malacolite, and to be completely paralleled by crystalline configurations in the coccolite marble of Aker in Sweden, and in the crevices of a crystal of spinel embedded in a calcite matrix from Amity, New York.

Finally, they argued that the occurrence of the Eozoon solely in crystalline or metamorphosed rocks, and never in ordinary unaltered deposits, must be assumed as completely demonstrating their purely mineral origin. The paper was aggressively argumentative from the start and contains a very scathing review of Dawson's work, further expressing a willingness to renounce the controversy altogether, "fully believing that Doctor Dawson can employ his time more usefully on other subjects than that of Eozoon."

The evidence, however, was not altogether one way. Max Schultze, after an examination of a specimen transmitted him by Dawson, announcing that "there can be no serious doubt as to the foraminiferal nature of *Eozoon canadense*." Further evidence against the organic nature of the Eozoon was, however, furnished by Mr. H. J. Carter in 1874, in a letter to Professor King, and published in the Annals and Magazine of Natural History of that year. After a somewhat elaborate comparison of the structure of Eozoon with that of known foraminifera, he wrote:

> But in vain do we seek in the so-called *Eozoon canadense* for an unvarying perpendicular tubuli, the *sine qua non* of foraminiferal structure. * * * In short, in vain do we look for the casts of true foraminiferous chambers at all in the grains of serpentine. They, for the most part, are not subglobular but subprismatic. With such deficiencies I am at a loss to conceive how the so-called *Eozoon canadense* can be identified with foraminiferous structure except by the wildest conjecture.

To the conclusions of Carter, Carpenter took violent exception and accused that gentleman of not having read anything that had been written bearing upon the other side of the question; of having no comprehensive knowledge of foraminiferal structure, and of having seen only those samples of Eozoon submitted by Professor King; and hence his imputation to the effect that the organic nature of the Eozoon had no other basis than "the wildest conjecture" was to be regarded "simply as specimens of a new method of language which might be termed *Carterese*." He then went over once more certain disputed points and concluded by saying:

> An experience of thirty-five years * * * has given me, I venture to think, some special aptitude for recognizing organic structure when I see it; and I never saw, in any fossil whatever, more distinct evidences of organic structure than are to be seen in these finer ramifications of the canal system of Eozoon.[a]

Perhaps the most important paper on the subject after those mentioned was that of Dr. Carl Moebius, of Kiel, in 1879. Moebius, it should be noted, was a zoologist and microscopist. He claimed to have been first led to the study of the Eozoon through observations of the structure of a rhyzopod found by him in 1874 on the coral reefs near Mauritius. Sections of these growths so closely resembled the representations of Eozoon sections published that he resolved to make a careful investigation of the latter for purposes of comparison with his *Carpentaria raphidodendron* and other foraminifera. With this object in view, he investigated upward of 90 Eozoon sections, which were placed at his disposal through the kindness of Doctor Carpenter, and many of which originally belonged to Professor Dawson.

[a] "For treweley there is noon of us all,
If any wight wol claw us on the galle,
That we nyl kike."

The result of Moebius's work was not at all, presumably, what Carpenter was led to expect or Dawson to hope. He wrote:

My task was to examine the Eozoon from a biological point of view. I commenced it with the expectation that I should succeed in establishing its organic origin beyond all doubt, but facts led me to the contrary. When I saw first the beautiful stem systems in Professor Carpenter's sections, I became at once a partisan of the view of Professor Dawson and Professor Carpenter, but the more good sections and isolated stems I examined the more doubtful became to my mind the organic origin of Eozoon, until at last the most magnificent canal systems taken altogether and closely compared with foraminiferal sections preached to me nothing but the inorganic character of Eozoon over and over again.

Dawson thereupon became particularly indignant, and characterized Moebius's work as furnishing "only another illustration of partial and imperfect investigation, quite unreliable as a verdict on the question in hand." He claimed that Moebius should have studied the fossil *in situ* and in its various stages of preservation; that he confounded the "proper wall" with the chrysotile veins traversing many of the specimens; and that, further, in his criticisms he regarded each structure separately, and did not "consider their cumulative force when taken together." This cumulative force he presented as follows:

1. It (i. e., *Eozoon*) occurs in certain layers of widely distributed limestones, evidently of aqueous origin, and on other grounds presumably organic.

2. Its general form, lamination, and chambers resemble those of the Silurian *Stromatopora* and its allies, and of such modern sessile foraminifera as *Carpentaria* and *Polytrema*.

3. It shows under the microscope a tubulated proper wall similar to that of the nummulites, though of even finer texture.

4. It shows also in the thicker layers a secondary or supplemental skeleton with canals.

5. These forms appear more or less perfectly in specimens mineralized with very different substances.

6. The structures of Eozoon are of such generalized character as might be expected in a very early Protozoan.

7. It has been found in various parts of the world under very similar forms, and in beds approximately of the same geological horizon.

8. It may be added, though perhaps not as an argument, that the discovery of Eozoon affords a rational mode of explaining the immense development of limestones in the Laurentian age; and on the other hand that the various attempts which have been made to account for the structures of Eozoon on other hypotheses than that of organic origin have not been satisfactory to chemists or mineralogists, as Doctor Hunt has very well shown.

Singularly enough, although found on the Western Continent, active work regarding the nature of the Eozoon was confined largely to the Canadians and English, with an occasional European collaborator, workers in the United States taking little part in the dispute so far as indicated by literature, although watching the contest with interest and becoming more or less partisans, according to the extent of their own observations or the character of the evidence offered. In 1871 Messrs. Burbank and Perry made a study of the Eozoonal limestone occurring at Chelmsford, Bolton, and Boxboro, in Massachusetts, and arrived at the conclusion that the limestones were not themselves of a sedimentary, but a vein-like character, and that consequently the Eozoon itself, as there occurring, must be of mineral and not organic origin.

Meantime the study of micro-petrography was steadily advancing, and it was noticeable that none of the workers along these newly developed lines of research were disposed to regard the Eozoon as of other than inorganic origin. Prof. T. G. Bonney, of St. John's College, Cambridge, England, who in 1876 announced his opposition to the theory of organic origin, in 1884 visited one of the most noted of the Canadian localities in company with Doctor Dawson, and published the results of his observations in the Geological Magazine for 1895, but contented himself with describing the mode of occurrence and structure of the mass without committing himself further as to its

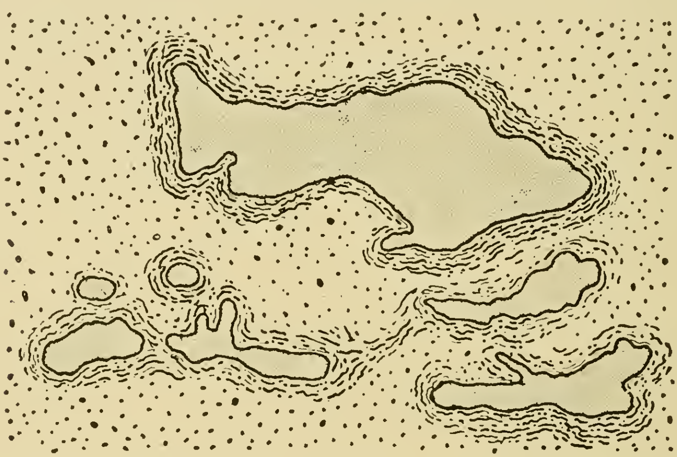

FIG. 129.—Diagram of eozoonal rock at Côte St. Pierre. The closely dotted part is pyroxene or serpentine; the top mass being about 2 feet 3 inches long. The zones of "Eozoon" are indicated by the broken wavy lines generally surrounding these masses. The remainder of the rock is white crystalline limestone spotted with granular serpentine. (After T. G. Bonney.)

origin. From this paper was taken the accompanying figure. His conclusions so far as given were to the effect that the Eozoon often occurs in close relation, on the one hand, with a fundamental mass of almost pure pyroxene (or serpentine resulting from its alteration); or, on the other hand, with a fairly large mass of crystalline limestone containing more or less numerous grains of pyroxene or serpentine. He found nothing to lead him to think the Eozoonal specimens were blocks of foreign material metamorphosed by becoming included in either a volcanic or plutonic mass as has been suggested (see p. 645). The structure, to his mind, offered a choice between two interpretations only. It "is either a record of an organism or a very peculiar and exceptional condition of a pyroxene marble of Laurentian age."

The fact that the lime-magnesian pyroxenes, through a process of chemical metamorphism, passed over into serpentine, and that many of the supposed sarcode chambers were filled with granules of this material in all stages of this alteration was from time to time noted by Messrs. King and Rowney, Julien, Williams, Wadsworth, Merrill, and others. The evidence thus presented was, however, wholly without effect on Messrs. Carpenter and Dawson, who to the very last remained true to their convictions, and as late as 1895 Dawson reviewed the subject with seeming thoroughness and announced his original opinion as unchanged.

It remained, however, for J. W. Gregory and H. J. Johnston-Lavis, to give the deathblow to the theory as late as 1891 and 1894. Gregory, from an exhaustive study of Dawson's original specimen of the so-called Tudor Eozoon, arrived at the conclusion that the same was wholly of an inorganic nature. After a careful examination of all the slides and figures, he wrote:

> I must confess myself absolutely unable to recognize in the specimen any trace of the proper wall, canals, or stolon passages which are claimed to occur in Eozoon.

The case against the organic nature of the specimen did not, however, rest upon negative evidence alone. The rock was intensely cleaved and crumpled. The twin laminæ in the planes of crystalline cleavage in the calcite bands were, however, not bent. Further than this, the bedding plane could be traced directly across the specimen, traversing the limestone in the supposed body cavities. These facts would seemingly prove conclusively that the supposed organic forms were not original, but wholly secondary and due to metamorphism.

Johnston-Lavis's later work was perhaps even more decisive, since he showed that structures in every way similar could be produced by the action of heat upon limestone. His conclusions were based upon an examination of microscopic slides from blocks of limestone in the volcanic tuffs of Monte Somma. To appreciate his evidence it must be remembered that these blocks are ejected from the volcano and are found embedded in a tuff consisting largely of pumiceous lava. They occur as irregular, angular, or subangular masses ranging to more than a cubic meter, though commonly less than a quarter of that size. They have been acted upon by the heat and vapors of the volcano and more or less completely metamorphosed, giving rise to various silicate minerals, including pyroxene, olivine, epidote, mica, etc. The structure of these altered limestones is entirely different from that of the unaltered material, and corresponds in all details with those of the original Canadian specimens, in many cases, on account of their freshness, exhibiting some of the pseudo-organic structure details—such as stolon passages—in far greater perfection than does the true so-called Eozoon.

It has been noted that American workers took comparatively little part in active research, though it does not necessarily follow that examinations of the problematic bodies were not made sufficient to enable them to hold opinions of their own. It is interesting, therefore, to note that few of the active workers accepted unhesitatingly the organic theory, and many of them rejected it entirely. The consensus of opinion to-day is so decidedly against the organic nature of the body that it may be considered as practically settled, although Dana, in the latest issue of his Manual, includes a copy of one of Dawson's original figures, and sums up the evidence pro and con without prejudice.

There is apparently no doubt but that this simulative form is due merely to a process of chemical metamorphism, a process of indefinite substitution and replacement, technically *metasomatosis*, acting upon rocks which are granular aggregates of lime-magnesian pyroxenes, with more or less calcareous matter, the serpentine being, in all cases, secondary. Such an origin is suggested at once, even to the uninitiated, by reference to figures like that of Bonney's, on page 644. Similar structures have, moreover, been noted by various observers in rocks which were unmistakably of igneous origin.

Specialization is, undoubtedly, essential to the rapid advancement of knowledge, but there is danger of specialization being carried too far—danger that the individual, through insufficient breadth of training or through too close application to his own particular hobby, may ignore the work of his neighbor along other lines, and perhaps in time become so immune as to be unable to appreciate that work, even when its details are laid before him.

In the review of the Eozoon question, much must be allowed for the growth of science—the gradual increase in knowledge regarding both mineral structure and mineral alteration. Still, one who peruses these papers can but feel that had Messrs. Dawson and Carpenter had a little more knowledge of mineralogy they would have been less dogmatic in their assertions, and it is possible that had Messrs. King and Rowney had more knowledge of foraminiferal structure they might have been less harsh in their criticisms.

> "'My children,' the chameleon cries,
> (Then first the creature found a tongue,)
> 'You all are right and all are wrong.
> When next you talk of what you view,
> Think others see, as well as you,
> Nor wonder, if you find that none
> Prefers your eyesight to his own.'"

CHAPTER X.

THE LARAMIE QUESTION.

It will be recalled that Hayden, in his annual report for 1872, referred to the fact that during his explorations of the Tertiary formations along the upper Missouri River in 1854–55 he made large collections of shells and plants, many of which were quite new to science. During the succeeding years up to the autumn of 1860 these explorations were extended and large additions made to the collections, which were described from time to time in the current literature.

The shells were all of extinct species of fresh-water origin and, while they did not appear to be positively characteristic of any age, were regarded by Meek as more nearly resembling Tertiary types than any other. The fossil plants were mostly of extinct species and regarded by Newberry as also of Tertiary age, probably Miocene.

From evidence of this kind, accumulated during the various expeditions, Hayden had announced the conviction that these *Lignitic* strata, as he called them, which had been found to occupy such vast areas in the upper Missouri Valley—extending far southward, with very little interruption, to New Mexico, and westward into the interior of the continent—were probably all portions of one great group, interrupted here and there by mountain chains or concealed by more modern deposits, and from the identity of their fossil flora, all of Tertiary age.

He then went on to state that his studies of the lower coal beds at Bear River City, Wyoming, and Coalville, Utah, in 1868, had convinced him that these particular beds were of Cretaceous age, but admitting this, he felt, would be to admit the Cretaceous age of all the coal beds of the Northwest, and in so doing to ignore the evidence of the fossil flora altogether. The facts then at hand, he thought, seemed rather to point to the conclusion that the deposition of all the Lignitic strata began during the latter portion of the Cretaceous period and continued on into Tertiary time without any marked physical break, so that many of the Cretaceous types, especially of the vertebrata, may have lingered on through the transition period, even into the Tertiary epoch. Inasmuch as this statement contains the first satisfactory recognition of the full importance of what later became known as the Laramie question, and inasmuch, further, as the discussion brought out many interesting facts and opinions relative to the proportional value of the various kinds of fossil remains as horizon markers, the subject may be dwelt upon in some detail.

It is well to anticipate, however, in order to more readily understand what is to follow, that Hayden made a fundamental error in thus assuming an identity of age for all the lignite strata. Had he realized the fact, afterwards abundantly proven, that essentially similar conditions existed at various periods in localities not widely remote from one another, and which were productive of very similar results, the so-called "Laramie question," as it is known to-day, would never have arisen. The apparently conflicting character of the fossil remains of plants and animals was, nevertheless, extremely confusing, and some discussion and verbal warfare during the gradual accumulation of the necessary data for the final settlement of the problem was bound to arise. It will be well to note, further, that the localities from whence was derived the major portion of the evidence brought to bear were: Fort Union, Nebraska; the Judith River, on the upper Missouri, Montana; Coalville, Utah; and Bear River and Bitter Creek, in Wyoming. Incidentally, other localities in Colorado and New Mexico came in for discussion.

During the season of 1872 Lesquereux, Meek, and Cope were assigned by Hayden to work in areas which seemed to afford the most promising opportunities for deciding the question as to the precise position of the beds in the geological scale. Their reports as rendered in the annual reports for 1872–73 were widely divergent and did little more than to emphasize the existing confusion.

Lesquereux worked, of course, wholly from a paleobotanical standpoint. He explored the plant-bearing Cretaceous strata of the Dakota group and the valley of the Saline River, as well as the Smoky Hill Fork of the Kansas River and the Lignite formations of the Rocky Mountains from Trinidad to Cheyenne and along the Union Pacific Railroad to Evanston. He made extensive collections and studied the materials in great detail, comparing the forms found with those from sundry of the known geological horizons in Europe. The summary of his conclusions, as given in his own words, was to the effect

> That the great Lignitic group must be considered as a whole and well-characterized formation, limited at its base by the fucoidal sandstone, at its top by the conglomerate beds; that independent from the Cretaceous under it and from the Miocene above it our Lignitic formations represent the American Eocene.

Meek regarded the Coalville and Bear River beds as Cretaceous, but argued for the Bitter Creek beds that the entire absence among the invertebrate fossils yet found of *Baculites*, *Scaphites*, *Ancyloceras*, *Ptychoceras*, *Ammonites*, *Gyrodes*, *Anchura*, *Inoceramus*, and all of the other long list of genera characteristic of the Cretaceous certainly left its molluscan fauna with strong Tertiary facies. When, however, he came to consider these fossils in their specific relation he found that all, with possibly two or three exceptions, were new to science and quite different from those yet found either at Bear River or Coalville, or, indeed, elsewhere in any of the established horizons. He felt, therefore, that he could scarcely more than conjecture from their specific affinities to known forms what the probable age of the rocks might be in which they were found. He, however, called attention to the following facts relative to the age of the formation as found at Bitter Creek:

First. That it was conformable to an extensive fresh-water Tertiary formation above, from which it did not differ materially in lithological characters except in its containing numerous beds of coal.

Second. That it seemed also to be conformable to a somewhat differently composed group of strata below, apparently containing little, if any coal, and believed to be of Cretaceous age.

Third. That it showed no essential difference of lithological characters from the Cretaceous coal-bearing rocks at Bear River and Coalville.

Fourth. (Omitting references to Lesquereux's determinations) that all its animal remains thus far known were specifically different from any of those found in any other formation of this region, with possibly two or three exceptions.

Fifth. That all its known invertebrate remains were mollusks, consisting of about thirteen species and varieties of marine, brackish, and fresh-water types, none of which belonged to genera peculiar to the Cretaceous or any older rocks, but all to such as are alike common to the Cretaceous, Tertiary, and present epochs, with possibly one exception.

Sixth. That, on the other hand, two or three of its species belong to sections or subgenera apparently characteristic of the Eocene-Tertiary of Europe, and even very closely allied to species of that age found in the Paris basin, while one species seemed to be conspecific with and two congeneric with forms found in brackish-water beds on the upper Missouri containing vertebrate remains most nearly allied to types hitherto deemed characteristic of the Cretaceous.

Seventh. That one species of Anomia found in it is very similar to and perhaps identical with a Texas Cretaceous shell, while a *Viviparus*, found in one of the upper beds, is almost certainly identical with the *V. trochiformis* of the fresh-water Lignite formations of the upper Missouri, a formation which has always been considered as Tertiary.

He summed up his evidence as follows: It thus becomes manifest that the paleontological evidence bearing on the question of the age of this formation, so far as yet known, is of a very conflicting nature; though aside from the Dinosaur bones (found by him at Black Butte in 1872) the organic remains favor the conclusion that it is Tertiary. The testimony of the plants, however, on this point, although they doubtless represent what would be in Europe considered as clearly a Tertiary flora, is weakened by the fact that we already know that there is in Nebraska, in clearly Cretaceous rocks, a flora that was referred by the highest European authority to the Miocene.

In the report for 1873 (printed in 1874) Lesquereux returned once more to the subject and answered more or less satisfactorily various objections which had been made to his previous conclusions. He referred to the Eocene (Lower American Eocene) all the coal strata of the Raton Mountains; those of the Canyon City coal basin; those of Colorado Springs; those of the whole basin of central and north Colorado extending from Platte River or from the Pinery divide to south of Cheyenne, including Golden, Marshall, Bowlder Valley, Sand Creek, etc.; and in Wyoming, the Black Butte, Hallville, and Rock Spring coal. He considered as American Upper Eocene or Lower Miocene the coal strata of Evanston, and from identity of the characters of the flora, those 6 miles above Spring Canyon near Fort Ellis, those of the locality marked near Yellowstone Lake among basaltic rocks, and those of Troublesome Creek, Mount Brosse, and Elk Creek, Colorado. The coal from Bellingham Bay, in Washington, he would also refer to the same horizon. To the Middle Miocene he would refer the coal basin of Carbon and those of Medicine Bow, Point of Rocks, and Rock Creek; to the Upper Miocene. the coal of Elko Station, Nevada.

Concerning the evidence of invertebrates regarding the Cretaceous age of these beds, he simply remarks:

> I regarded and still regard the presence of some scattered fragments of Cretaceous shells as of little moment in comparison with the well-marked characters of the flora, characters which have been wholly established by a large number of specimens obtained from all the localities referred to the Lignitic.

Cope, in his report for this same year, was inclined to agree with Hayden in thinking that the period of the deposition of the sediments of this Lignite or Fort Union group, as it was also called, was one of transition from marine to lacustrine conditions and added:

> It appears impossible, therefore, to draw the line satisfactorily without the aid of paleontology, but here, while evidence of interruption is clear from the relations of the plants and vertebrate animals, it is not identical in the two cases, but discrepant.

He then went on to discuss the evidence as given by the various workers, and referring to Lesquereux and Newberry's opinions, based upon the flora, to the effect that the whole series of formations is of Tertiary age, summed up his results as follows:

I regard the evidence derived from the mollusks in the lower beds and the vertebrates in the higher as equally conclusive that the beds are of Cretaceous age. There is, then, no alternative but to accept the results that a Tertiary flora was contemporaneous with a Cretaceous fauna, establishing an uninterrupted succession of life across what is generally regarded as one of the greatest breaks in geological time.

Practically the same conclusion was independently arrived at by King in his study of the Green River coal basin in connection with the surveys of the fortieth parallel.[a] He wrote:

We have, then, here the uppermost members of the Cretaceous series laid down in the period of oceanic sway and quite freely charged with fossil relics of marine life; then an uninterrupted passage of comformable beds through the brackish period up until the whole Green River basin became a single sheet of fresh water.

It will be seen then that the transitional character of the beds was very generally recognized, the main point in dispute from now on being that of their Upper Cretaceous or Lower Tertiary age.

A. R. Marvine, in his report for this year (1873), also discussed the problem, but somewhat guardedly, since his opportunities for observation had confessedly been somewhat limited. He wrote, after summarizing the opinions of others:

It must be supposed, then, that either a Cretaceous fauna extended forward into the Eocene period and existed contemporaneously with an Eocene flora, or else that a flora wonderfully prophetic of Eocene times anticipated its age and flourished in the Cretaceous period to the exclusion of all Cretaceous plant forms.

Again, and much more to the point, he wrote:

Much of the confusion and discrepancy has, in my opinion, arisen from regarding different horizons as one and the same thing. It must be distinctly understood that this group as it exists east of the mountains in Colorado is very different from, and must not be confounded with, the horizon in which much of the Utah and New Mexican lignite occurs, and which belongs undoubtedly to the Lower Cretaceous; and, further, that the extended explorations of Hayden and others would seem to prove almost conclusively that the Colorado lignite group is the direct southern stratigraphical equivalent of the Fort Union group of the upper Missouri, which is considered generally to be no older than the Eocene, while Newberry asserts that it is Miocene.

To Lesquereux's conclusions in the report for 1872, Newberry, in an article in the American Journal of Science, 1874, took exception, calling in question the accuracy of many of his statements, and affirming that, to his "certain knowledge," a considerable portion of the flora he called Eocene was really Cretaceous and another portion Miocene. Further than that, having spent nearly two years in New Mexican explorations, he felt authorized to state that all the lignite beds yet known in New Mexico were unmistakably of Cretaceous age. While, through lack of acquaintance with the Colorado localities cited

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[a] The third volume, 1870.

by Lesquereux, he would not venture to doubt the truth of his assertions regarding the same, he nevertheless reminded him that: (1) The flora of the Colorado lignite beds had almost nothing in common with that of the European Eocene, in his judgment not a single species and scarcely any genera being common to both; (2) that the tuberculated fucoid (Halymenites), considered by Lesquereux as diagnostic of the Eocene, was really in New Mexico the most characteristic fossil of the Cretaceous; and (3) that, guided by their animal remains, Professors Marsh, Meek, Cope, and Stevenson had all regarded the Colorado lignites as Upper Cretaceous.

Newberry further contended that in the plant beds which he had himself designated as Miocene the entire aspect of the flora was identical with the Miocene of Europe, and contained a very considerable number of well-marked Miocene species, not one of which deserved to be called Eocene. The lignite plant beds of New Mexico, which he called Cretaceous but which Lesquereux referred to the Tertiary, were for the most part derived from the lower portions of our Cretaceous series, and were overlaid by many hundreds of feet of unquestionable Cretaceous strata in which all the typical Cretaceous forms were represented.

He further announced the principle that:

In the absence of any distinctive or unmistakably Eocene plants, if the strata which contain them (the lignite deposits) shall be found to include vertebrates or mollusks which have a decidedly Mesozoic aspect, we shall have to include them in the Cretaceous system.

To Lesquereux's claim that the testimony of his 250 species of fossil plants far outweigh that of the Cretaceous mollusks, he rejoined that these plants were probably all distinct from European Cretaceous and Eocene species and had little or no bearing on the question in hand. He acknowledged it was not impossible that the physical condition of the continent may have been such that the Cretaceous age faded gradually into the Tertiary, and that consequently some forms of Cretaceous life might be found interlocking with those of Tertiary age, but of this he demanded proof, and asserted that as yet none such had been found.

J. J. Stevenson, meeting with these same beds in his work in connection with the Wheeler Survey (1874), pronounced in favor of their Upper Cretaceous age. As for the nodose fucoid Halymenites, he agreed with Newberry that it was not indicative of their Eocene age, since it was never found with any but a Cretaceous fauna. Neither was the evidence of the land plants acceptable to him, the materials being mostly single leaves and in a state of preservation showing that they had been blown from trees growing near streams or on the shore, where they were washed into the sea and became associated with at least one fossil identified with the Cretaceous, and a few of which were identical with European species.

It was more reasonable, he thought, to suppose that in the later portion of the Cretaceous period the climate in our northwestern region was like that of the European Eocene than to imagine that our Cretaceous fauna is useless for determination of horizon in the narrow strip east of the mountains in Colorado, while acknowledging it to be decisively of Cretaceous age in New Mexico, the rocks being the same, but the leaves being absent.

To Newberry's criticisms Lesquereux replied[a] that the Cretaceous age of the so-called halymenites sandstone had not yet been proven and could not be decided on mere affirmation; but that when Doctor Newberry had furnished sufficient proof or evidence on the geological age of the lignites of New Mexico he was prepared to accept his decision. The quoted opinions of Marsh, Cope, and Stevenson he claimed were based on insufficient evidence. All the repeated assertions of the finding of fossil shells and bones of Cretaceous age in the lignites of Colorado, when carefully sifted down, reduced themselves to the finding of a single badly-preserved specimen of *Inoceramus*.

He asserted that the lignitic formation, having positively a preponderance of land plants over marine animals, in other words, being composed wholly of detritus from the land or a *land formation*, as he styled it, the evidence presented by the fossil plants should outweigh in importance that of some Cretaceous animal remains, whose presence could be considered as of casual occurrence. Cope's conclusions, he argued, did not in the least interfere with his own, simply proving the noncoincidence of animal and vegetable types in certain formations, but if, he added:

> Tertiary and Cretaceous faunas are regarded as contemporaneous, even inhabiting the same repositories, we may more easily admit that a Cretaceous fauna and Tertiary flora have sometimes succeeded each other in alternating strata.

Lesquereux further contended that the specimens on which Doctor Newberry had relied to substantiate the sum of the opinions he advanced had become mixed and had, in reality, come from different localities and represented different horizons.

In his report for 1874 (letter of transmittal written in October, 1875) Hayden took up the matter once more, with particular reference to the results of investigations in Colorado. These he felt warranted him in drawing the following conclusions:

First. That through the upper portion of the Fox Hill group (Cretaceous) there are clear proofs of a radical physical change, usually with no break in the sequence of time. In this portion of the group

[a] American Journal of Science, 1874.

are well-marked Cretaceous fossils of purely marine types and no others.

Second. That above the Fox Hill group there are about 200 feet of barren beds, which might be regarded as beds of passage to the lignitic group and which more properly belong with the Fox Hill group below. In this group of transition beds all trace of the abundant invertebrate life of the great Cretaceous series below has disappeared.

Third, in almost all cases he found, at the base of the true Lignitic group, a bed of sandstone in which the first deciduous leaves peculiar to the group occur. No purely marine mollusks pass above this horizon. Estuary or brackish-water shells are found in many localities in great abundance, but these soon disappear and are succeeded farther north by fossils of purely fresh-water origin. He added:

Whatever view we may take in regard to the age of the Lignitic group, we may certainly claim that it forms one of the time boundaries in the geological history of our western continent. It may matter little whether we call it Upper Cretaceous or Lower Eocene, so far as the physical result is concerned. We know that it plays an important and, to a certain extent, an independent part in the physical history of the growth of the continent. Even the vertebrate paleontologists, who pronounce with great positiveness the Cretaceous age of the Lignite group, do not claim that a single species of vertebrate animals passes above the horizon I have defined from the well-marked Cretaceous group below.

Peale, in his report for that year, threw a ray of light upon the subject by suggesting that the reason of the difference of opinion as to the age of the disputed beds might be the existence of two sets of lignite-bearing beds close together, one belonging to the horizon of the Fox Hill beds of the Cretaceous, or possibly a little above it, and the other belonging to the horizon of the Fort Union group (Lower Eocene). He incidentally called up the question relative to the value of different types of fossils as criteria in determining the precise geological horizon. He summed up his own conclusions as follows:

First. The lignite-bearing beds east of the mountains in Colorado are the equivalent of the Fort Union group of the upper Missouri, and are Eocene-Tertiary; also, that the lower part of the group, at least at the locality two hundred miles east of the mountains, is the equivalent of a part of the Lignitic strata of Wyoming.

Second. The Judith River beds have their equivalent along the eastern edge of the mountains below the Lignite or Fort Union group, and also in Wyoming, and are Cretaceous, although of a higher horizon than the coal-bearing strata of Coalville and Bear River, Utah. They form either the upper part of the Fox Hill group or a group called "Number Six."

In his annual report to Hayden for the same year (1874, printed in 1875), Lesquereux went over all the ground once more, showing to his own satisfaction, presumably, the conclusive character of the evidence offered by fossil plant remains, and announced again his conviction to the effect that the authority of animal remains should be unquestioned so far as it relates to marine formations, but when land formations are considered, the plant remains should be given precedence.[a]

Meanwhile, Dr. C. A. White, paleontologist, became connected with the Hayden survey, being assigned for his first season's work (1877) to the area of northwestern Colorado. In this connection he came quickly in contact with the problem we have been discussing, and early committed himself in favor of the post-Cretaceous age of the beds in question.

He argued that it was a well-known fact that the evolutional advance of the vegetable kingdom had been greater on this continent than in Europe. Hence, a student of the flora of the American strata, using a series of European standards, would naturally refer those which he found to contain certain vegetable forms to the Tertiary period, while the associated or superimposed remains of animal life might all show them to be of Cretaceous age, according to the same series of European standards.

Taking into consideration the fact that the physical changes which took place in western North America during the Mesozoic and Cenozoic periods were very gradual and without any important break, he would be led to expect to find those animals, whose existence was not necessarily affected by a change from a saline to a fresh condition of the waters, to have propagated their respective types beyond the period which those types in their culmination distinctly characterized. For this reason he felt that these perpetuated types did not necessarily prove the Cretaceous age of the strata, they being evidently the last of their kind, and because, moreover, all the other known fossil remains of the group indicated a later period. He would, therefore, refer the beds, which had now, according to an agreement between King and Hayden, become known as the *Laramie*, to a post-Cretaceous age.

Referring again to the matter in his report for 1877, White conceded that Cretaceous types (dinosaurs) of vertebrate animals were found in the higher strata of the Laramie group and did not question the correctness of referring the plant remains even of the very lowest beds to the Tertiary; noting also that the invertebrate fossils were indecisive, since the species were new to science and could not be safely compared with those found elsewhere. Without committing himself, he then offered a suggestion in effect as follows: Since none of the American Cretaceous could be considered as equivalent to the Lower Cretaceous of other parts of the world, but must be considered as

[a] Marsh, it may be noted incidentally, in 1877, in discussing the problem of the boundary between the Cretaceous and Tertiary, announced that in his opinion the evidence of the numerous vertebrate remains was decisive in favor of the Cretaceous view.

Upper Cretaceous, these Laramie rocks which, if Cretaceous at all, were certainly at the very top of the Upper Cretaceous, must represent a great and important period wholly unrepresented in any other part of the world.

Further, the finding of evidence of an abundant mammalian life (Tertiary) immediately following the Laramie period, which in itself contained only Cretaceous vertebrate remains (dinosaurs), suggested to him a sudden ushering in of the Tertiary types which could be accounted for only on the supposition that such originated elsewhere, and were contemporaneously in existence with the Cretaceous forms, i. e., prior to the close of the Laramie period. Their apparent sudden appearance could then be accounted for on the supposition that the physical barrier was removed by some of the various earth movements connected with the evolution of the continent.

To these same opinions he held in his report for 1878, adding that, if the conclusions of all the leading paleontologists regarding the Eocene-Tertiary age of the Wasatch, Green River, and Bridger groups be accepted, "then is there additional evidence of the correctness of the view that the Laramie is a transitional group between the Cretaceous and Tertiary, partaking of the faunal characteristics of both periods."

Hayden, in his report for this year (1878), argued that the Fort Union beds of the upper Missouri River are the equivalent of the Lignitic formation, as it exists along the base of the Rocky Mountains in Colorado, and of the Bitter Creek series west of the mountains; also that it was probable that the brackish-water beds on the Upper Missouri must be correlated with the Laramie, and that the Wasatch group, as now defined, and the Fort Union group are identical as a whole, or in part, at least.

In his report on the systematic geology of the Fortieth Parallel Survey (1878), King again attacked the advocates of the Eocene age of these beds. He reviewed the evidence and announced his convictions, as before, in favor of their being Cretaceous.

He agreed with Hayden in regarding the Laramie and underlying Fox Hill as strictly conformable, but found a very decided unconformability between the uppermost Laramie containing the dinosaur remains and the immediately overlying rocks of the Vermilion Creek group, which carried mammalian remains. The unconformity here mentioned for the first time is, with the exception of the suggestion made by Peale, perhaps the most important feature yet introduced into the discussion, and it is probable, as elsewhere suggested by King, that had Hayden seen this locality earlier, the question as to the exact position of the Laramie beds might never have arisen.

His conclusions, as summed up in his recapitulation of the Mesozoic, are as follows:

The Laramie, by its own vertebrate remains, is proved to be unmistakably Cretaceous and the last deposit of that age, and it contains no exclusively fresh-water life. Its plants resemble European Tertiary, but its Dinosaurs are conclusive of Cretaceous age. It was the last of the conformable marine deposits of middle America. Its latest period of sedimentation was immediately followed by an energetic orographic disturbance, which closed the Mesozoic age. In that orographic action the inter-American ocean was obliterated and the Cretaceous locally thrown into great and steep folds. The following deposits over the Green River area were fresh-water lacustrine lowest Eocene strata, lain down nonconformably with the Cretaceous, except in accidental localities.

In 1885 the problem was taken up by L. F. Ward in an exhaustive paper on the Flora of the Laramie Group. This, although destructive in its criticism rather than decisive, nevertheless contained many important suggestions. After a summary of opinions held by previous workers, he wrote:

Taking all these facts into consideration, therefore, I do not hesitate to say that the Laramie flora as closely resembles the Senonian (Cretaceous) flora as it does either the Eocene or the Miocene flora, but I would insist that this does not necessarily prove either the Cretaceous age of the Laramie group or its simultaneous deposit with any of the Upper Cretaceous beds. The laws of variation and geographical distribution forbid us to make any such sweeping deductions. With regard to the first point, it is wholly immaterial whether we call the Laramie Cretaceous or Tertiary, so long as we correctly understand its relations to the beds above and below it. We know that the strata immediately beneath are recognized Upper Cretaceous, and we equally know that the strata above are recognized Lower Tertiary. Whether the first intermediate deposit be known as Cretaceous or Tertiary is, therefore, merely a question of name, and its decision one way or another can not advance our knowledge in the least.

In this, it will be noted, he followed closely the opinions already expressed by Hayden.

Other statements of Ward's in this connection are worthy of consideration. He pointed out that there was no probability that the conditions existing during the Laramie deposition would be ever exactly reproduced elsewhere, and hence the chances were as infinity to one against the existence of other beds that should contain an invertebrate fauna identical with that of the Laramie group. Further than this, he regarded the law laid down by paleontologists that the same epochs in geologic time produced the same living forms, as quite contrary to the now well-established principles of geographical distribution.

Amidst all this confusion and conflict of opinion, the fact was becoming more and more apparent that under the term *Laramie* had been included beds belonging to various but not widely separated horizons. King and Hayden, it will be recalled, had believed it to contain all the coal beds of the region in which it occurs and to be sharply circumscribed both above and below, the main point in dispute being whether it should be relegated to the Cretaceous or the Tertiary. As time went on, but particularly after the organization of the present survey, more careful and detailed work became possible. The Bear River beds were shown by Drs. C. A. White and T. W. Stanton, in 1891, to belong to the marine Cretaceous; the upper portion in Colorado and Wyoming was found by Cross, Hills, and Weed to be out of harmony with that beneath, and was relegated to the Eocene-Tertiary; the Laramie proper becoming more and more restricted as the work of differentiation went on.

In 1897 Drs. F. H. Knowlton and T. W. Stanton, the one a paleobotanist and the other a paleontologist, together made a personal inspection of many of the important localities, and, after passing the evidence in review, concluded that the so-called Ceratops beds of Converse County, Wyoming, should be referred to the Laramie group; that the coal-bearing series of the Laramie Plains is older than the "true" Laramie, and, instead of conformably overlying the Fox Hills group, is itself overlain by it.

The Bitter Creek and Black Buttes beds they considered as belonging to the "true" Laramie, and also those of Crow Creek, Colorado, while those of Point of Rocks, in the Bitter Creek Valley, were regarded as Cretaceous (Montana). The base of the Laramie (after a review of the opinions of Hatcher, Hills, King, and Hayden) they would place "immediately above the highest marine Cretaceous beds of the Rocky Mountain region," the top being marked by the Fort Union beds. In other words, the Fort Union beds are now regarded as Eocene and the lower-lying as Laramie Cretaceous.

Both these workers, it is well to note, conformed to the generally received opinion that "marine invertebrates (fossils) are more accurate and definite horizon markers than either plants or nonmarine invertebrates, because they have a less extended vertical and a broader geographic distribution."

O. C. Marsh, the reader will perhaps remember, had in 1891 announced the general principle that all forms of animal life are of value as horizon markers "mainly according to the perfection of their organization or zoological rank." Following out this principle, he regarded plants as unsatisfactory witnesses, invertebrates as much better, and vertebrates as the best of all, as offering "reliable evidence of climatic and other geological changes."

CHAPTER XI.

THE TACONIC QUESTION.

"Now, who shall arbitrate?
  Ten men love what I hate,
Shun what I follow, slight what I receive;
  Ten, who in ears and eyes,
Match me; we all surmise,
  They, this thing, and I, that;
Whom shall my soul believe?"

It is presumably scarcely necessary to call attention to the fact that the older rocks of the earth's crust are exposed, in a majority of cases, only where this crust has been disturbed through such folding and faulting as is incidental to mountain making. As a result of such processes these older rocks are, in the main, considerably altered and their origin as well as geological age at times quite indeterminable.

The attempt to fix the base of the Paleozoic strata or, in other words, to find a line of demarkation and division between the non-fossil-bearing and the most ancient members of the overlying fossiliferous strata has, therefore, proven a matter of the greatest difficulty both in America and abroad. In Great Britain and on the Continent manifestation of this is found in the voluminous literature relating to Sedgwick's Cambrian and Murchison's Silurian systems. In America a similar controversy was contemporaneously waged, which has come down to history under the name of the Taconic question.

In his report on the second geological district of New York, published in 1842, Ebenezer Emmons gave his first detailed account of the Taconic system. A review of the subject may well, therefore, begin with this paper, though an occasional earlier reference may be necessary.

In his report for 1838 Emmons had stated that the Potsdam sandstone was the oldest sedimentary rock occurring in the vicinity of Potsdam (New York) and that no rock intervened between it and the primary. In this opinion, to which he ever afterwards adhered, he was quite correct. Overlying the Potsdam sandstone and always in the same order he found the Calciferous sandrock, the Chazy, Bird's-eye, and Trenton limestones, the Utica and Hudson River slates, etc.

An examination of the country at the foot of the Hoosac Mountains in western Massachusetts showed what appeared to him an entirely different series resting, like the Potsdam, directly upon the gneiss, but in which none of the rocks of the previous series appeared. This series was described in his own words as below, the order of superposition

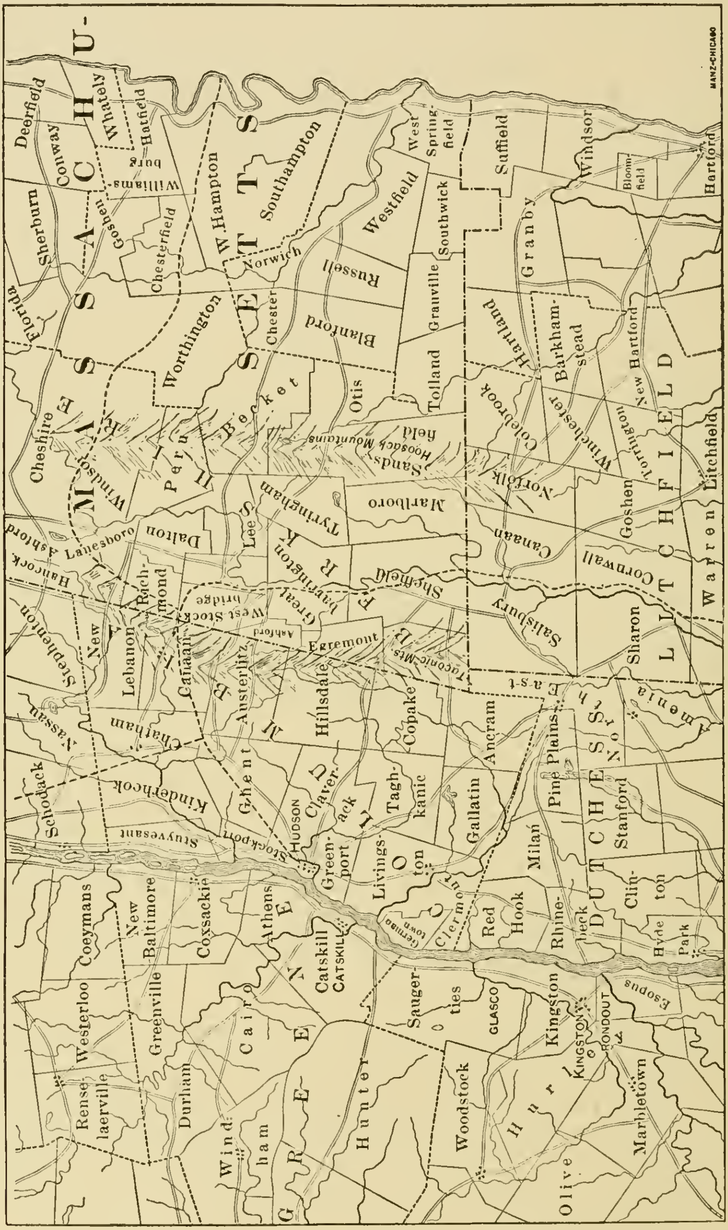


FIG. 130.—Map of original Taconic area.

being shown in the section reproduced herewith which the reader will note is given in a reversed position, the left being east and the right west (fig. 131):

1. A coarse granular limestone of various colors which I have denominated the *Stockbridge limestone*, taking its name from a well-known locality, one which has furnished the different parts of the Union a large portion of the white and clouded marbles which have been so extensively employed for building and other purposes in construction.

2. *Granular quartz rock*, generally fine grained, in firm, tough, crystalline masses of a brown color, but sometimes white, granular, and friable.

3. Slate, which for distinction I have denominated *Magnesian slate*, from its containing magnesia, a fact which is distinctly indicated by the soft feel peculiar to rocks when this earth forms a constituent part.

4. Sparry limestone, generally known as the *Sparry limerock*.

5. A slate, which I have named *Taconic slate*, and which is found at the western base of the Taconic range. It lies adjacent to the Lorrain or Hudson River shales, some varieties of which it resembles. In composition it contains more alumina and less magnesia than the magnesian slates.

The series occupied an area extending from the Hoosac Mountains westward, passing over the Hoosac Valley, Saddle Mountain, and also over the high ridge of granular quartz known as Oak Hill, just north of the Williamstown Plain, the Taconic Mountains next west of the Massachusetts boundary, and the eastern border of New York west of this boundary to the Hudson.

To this series, which Emmons conceived to be older than the Potsdam, he proposed in 1841 to give the name Taconic, after the Taconic

FIG. 131.—Section of Taconic Rocks. A, Primary schists; 1, granular quartz, or brown and white sandstone; 2, 2, Stockbridge limestone; 3, 3, magnesian slate; 4, Sparry limestone; 5, Taconic slate; 6, roofing slate; 7, rough coarse siliceous beds; 8, flinty slate; 9, Hudson River shales. (After E. Emmons.)

range, elevating it to the dignity of a system. His persistent advocacy of the actuality of this system gave rise to a controversy extending over more than half a century and equaled by none in the annals of American geology, not exceeded even by the Eozoon question noted elsewhere. Unmoved by argument, to the day of his death Emmons adhered faithfully to his "system," although from the very first he noted its most inherent weakness—that in no case had the Potsdam sandstone been found resting upon any of its members. That this system was actually an older, lower-lying series was indicated only by the fact that neither were any of its members found intercalated with the overlying series, which always occupied the position and relationship given above.

It must be remarked, by way of preliminary explanation, however, that the region, as shown by subsequent studies, is one where faulting, folding, erosion, and metamorphism have prevailed to an extent then undreamed of, and where, as a consequence, all natural criteria had become so obscured as to make a prompt solution of the problem impossible. The science of geology grows through cumulative evidence. The greatest minds and the most acute of observers were bound, by the then existing condition of knowledge, to make incomplete observations and faulty deductions.

The original section, as noted, was some fifteen miles in length.

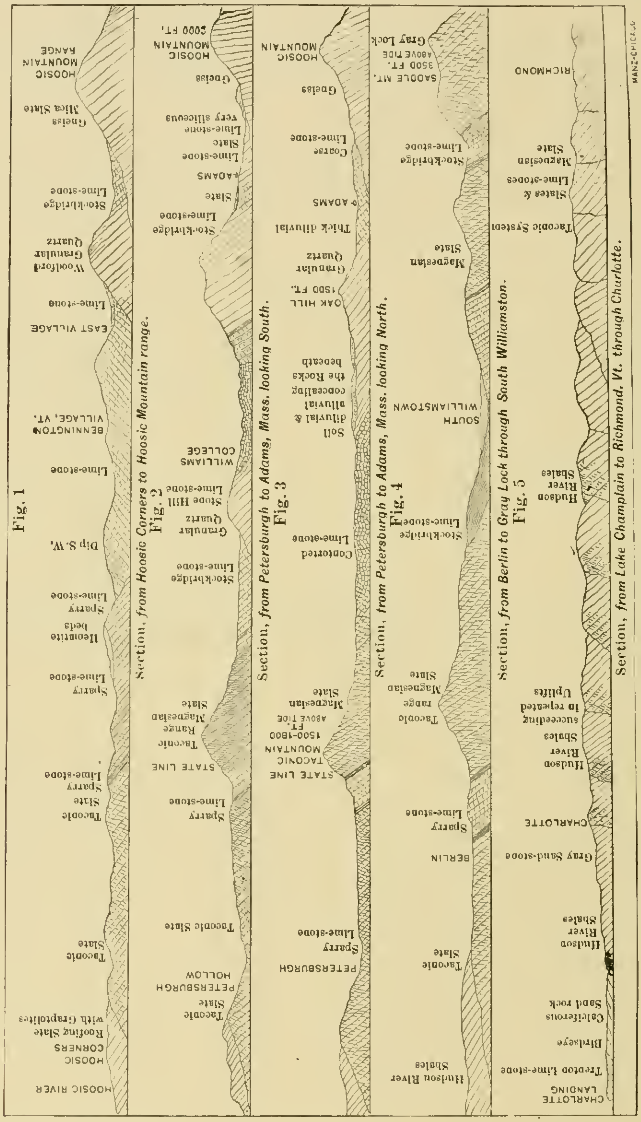


FIG. 132.—Sections explanatory of the Taconic system. (After E. Emmons.)

The rocks were all pronounced as unfossiliferous and dipped throughout to the eastward, their relative ages being judged wholly by superposition, the Stockbridge limestone, where it rested immediately upon the gneiss, being regarded as the oldest of the series.

The first announcement of this conclusion appears to have been made at the Philadelphia meeting of the American Association of Geologists and Naturalists, held in April, 1841. Unfortunately neither the paper nor the discussion which followed was printed in detail. It is stated by Dana, however, that the matter was discussed by H. D. Rogers, Edward Hitchcock, William Mather, James Hall, and Lardner Vanuxem, all of whom had worked in the region. It is stated, further, that none of the gentlemen, with the exception of Vanuxem, favored the views put forward by Emmons.

During the summer following both Rogers and Hall studied the section, as described by Emmons, in the field, Rogers rendering a report to the American Philosophical Society at Philadelphia at the meeting in 1842. In this report Rogers sustained the views previously advocated by Hitchcock, Hall, Mather, and himself, to the effect that the rocks were Lower Silurian (as the term was then used) extending from the Potsdam upward, but much flexed and disguised by partial metamorphism. Hall for some reasons failed to make a report at the time, though later claiming to have written out his notes very fully (see p. 671).

In his paper in the Report on the Geology of the Second District of New York, in 1842, where the system is first elaborated, Emmons referred to Rogers's conclusions, and seemingly himself recognized the possibility of the various beds of limestone being but portions of the same bed, brought to the surface by successive uplift. He did not, however, regard the same as probable. The system as a whole he thought to be the equivalent of the Lower Cambrian of Sedgwick, the upper portion being the lower part of the Silurian system.

Although the Proceedings of the American Association of Geologists were not given in full, as already noted, the opinions of Mather regarding the Taconic have fortunately been handed down to us in his Report on the Geology of the First New York District, dated 1843. In this he made use of the term in his descriptions, but stated emphatically that the "Taconic rocks are the same in age as those of the Champlain division, but modified by metamorphic agency and the intrusion of plutonic rock."

In December, 1844, Emmons brought out in pamphlet form a revision of the Taconic system, with additions and an extension of its limits. This was published without change as a chapter in his Report on the Agriculture of New York, under date of 1846. The most important feature of this revision related to the finding of fossil crustacean remains in the Black slate of Bald Mountain, in Washington County, New York. These he accounted for on the supposition that the beds, instead of being the lowermost, as he first supposed, belonged in reality to the top of the series, and had come into their present position through a reversion of the strata, adopting thus in part Rogers's ideas as to flexures and overthrust faults. The order of succession of the strata would then stand as below, that given in the paper of 1842 being introduced for comparison. It will be at once noted, as later charged by Dana (1888), that "the system is for the most part turned the other side up."

Taconic system, 1842.	*Taconic system, December, 1844.*
6. Stockbridge limestone.	6. Black slate, Bald Mountain.
5. {a. Magnesian slate of Greylock—perhaps a repetition of No. 3. b. Granular quartz.}	5. Taconic slate.
4. Limestone.	4. Sparry limestone.
3. Magnesian slate of Taconic Mountain.	3. Magnesian slate.
2. Sparry limestone.	2. Stockbridge limestone.
1. Taconic slate.	1. Granular quartz.

The system as here outlined, Emmons argued, occupied a position inferior to the Champlain division of the New York system, or the lower division of the Silurian system of Mr. Murchison.

FIG. 133.—*Atops trilineatus.*

The fossils found in the Black slate, it should be mentioned, were Trilobites—*Atops trilineatus*, a form allied to *Triarthrus beckii* and *Elliptocephala asaphoides*, and annelid markings, chiefly those of *Neireites* and *Myrianites*. These were described by Hall in 1846, and the ground taken that the *Atops* and *Triarthrus* were identical and referable to the Hudson River group, the *Elliptocephala* being referred to the genus *Olenus*,[a] an Upper Cambrian form.

At the Boston meeting (1847) of the Association of American Geologists and Naturalists, Prof. C. B. Adams discussed the Taconic rocks of the northern part of Addison County, Vermont, a locality judged to be particularly favorable for study, since the rocks pass here from a highly to but slightly metamorphosed and disturbed condition. He exhibited sections of Snake and Bald mountains and from Lake Champlain to the Green Mountains, and thought to show that the Taconic quartz rock was probably the metamorphic equivalent of the red sandrock (regarded by Adams as belonging to the Champlain division of the New York geologists), and that the Stockbridge limestone was the equivalent of the calcareous rocks overlying the red sandrock, rather than that of the lower limestone of the Champlain division.

[a] Later, *Olenellus* of the Lower Cambrian.

Inasmuch as the value of the evidence furnished by the fossil remains had become largely a matter of individual opinion, a committee, of which Mr. S. S. Haldeman was chairman, was appointed at the same meeting of the association to investigate. The report, as given by this committee in the American Journal of Science for 1848, was to the effect that so far as could be determined from the fragmental character of the specimens submitted, *Atops* and *Triarthrus* were not identical, but *A. trilineatus* was "a fossil characteristic of the stratum investigated and named by Professor Emmons."

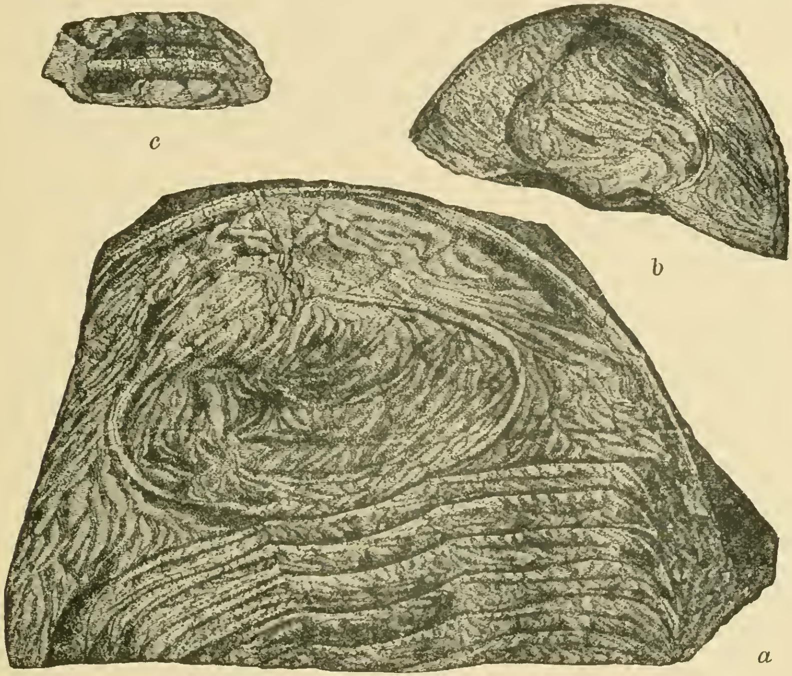


FIG. 134.—*Elliptocephala asaphoides*. *a* is a large individual much flattened by pressure: the natural joints of the slate pass through the specimen. The tail and a portion of the body are wanting. I have named this *Elliptocephala asaphoides*. The ellipse upon the buckler appears to be a characteristic marking, while the ribs and middle lobe resemble very strongly the same parts of the Asaphus tyrannus. In its perfect form the ellipse seems to belong to the old and perfect individual. *b* is the head of a small individual of the same species. The ellipse in this individual has an anterior segment not to be seen in *a*, which I suppose may be obliterated by age. *c* is a fragment of a trilobite, probably, but the ribs bear a different character from those we generally meet with.

To this report Hall naturally took exception, and in the Journal for the same year reviewed the subject and published figures giving reasons for thinking that the distinctions noted by the committee were not "actual and constant," but merely those of individuals, and reaffirming the statement that the two forms were essentially identical. Hall was in turn replied to by Emmons, but nothing conclusive was brought forward.

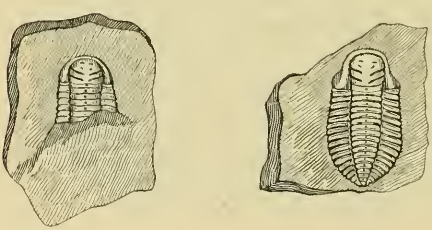
In 1849 the ubiquitous Hunt entered the field, siding, as it chanced, with the opinions of the opponents of the system, though later he shifted his ground. No new facts were, however, presented, and the matter is mentioned here only on account of the characteristically emphatic and apparently decisive manner in which his opinions were expressed, however fanciful may have been their basis.

Little of consequence now occurred until 1855, when Professor Emmons brought out his volume on American Geology, in which he made his third presentation on the subject. In this he extended the system from Maine to Georgia and subdivided it into an upper and lower portion, the fossiliferous portion being called the Upper Taconic and the nonfossiliferous the Lower Taconic. The Sparry and Stockbridge limestones were brought together as one formation, while the synclinal character of Mount Greylock was recognized and figured.

Taconic system in 1855.

Upper Taconic.	2. Black slate of Bald Mountain.
	1. Taconic slate.
Lower Taconic.	3. Magnesia slate.
	2. Stockbridge limestone.
	1. Granular quartz.

As here given, the system, as stated by Dana with reference to that of 1844, had a top and bottom of Cambrian rocks. The succession in the Lower Taconic was the same as in the publication of 1844.



a *b*

FIG. 135.—*a, Triarthus beckii; b, Triarthus eatoni.*

In 1854 or 1855 trilobites related to those of Bald Mountain were found in the Black slates of West Georgia, Vermont. Passing into the hands of Zadock Thompson, the assistant in the geological survey of the State, the specimens were sent to Professor Hall, and in 1859 were figured and described as belonging to the shales of the Hudson River group, one of the minor subdivisions of the Lower Silurian system, under the names of *Olenus thompsoni*, *O. vermontana*, and *Peltura holopyga*, the beds being thus, in his opinion, made equivalent to the Bald Mountain slates already noted. In this he was, however, in error.

The problem was not, however, confined to American soil. In 1856 there were found in the limestone belonging to the so-called graywacke series at Point Levi, opposite Quebec, a trilobite fauna of a nature sufficient to convert the paleontologist, Elkanah Billings, of the Canadian survey, to the views of Emmons, and cause him to affirm that the graywacke group lay below the Trenton in stratigraphic position."[a] In this view Logan at first acquiesced, but applied to the beds as there developed the name *Quebec* rather than Taconic, subsequently extending the name to the whole belt of Taconic rocks reaching from the St. Lawrence to the Hudson River.

In 1860 Barrande, the eminent Bohemian paleontologist and authority on the Silurian, read before the Geological Society of France a memoir in which he adopted in full the conclusions of Emmons regarding the Taconic system, pronouncing the Georgia, Vermont, trilobites as unquestionably of Primordial age and characteristic of a great Taconic system extending far below the *Olenus* or *Paradoxides*[b] zone.

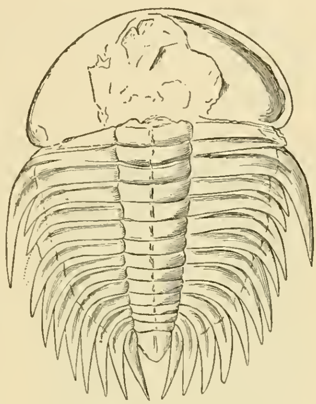


FIG. 136.—*Olenus thompsoni.*

Subsequent discoveries seemed to show that Barrande was misled through the character of the evidence available, he himself not having studied the question in the field. Be this as it may, his accession to the ranks of the "Taconists" for a time greatly strengthened their cause, through sheer weight of authority, and did much to complicate the situation, while the use made of his writings and personal letters by Marcou swelled the literature and confused the question until for a time the correct solution seemed hopeless. And here it may be remarked that, however conclusive and convincing the writings of Marcou may appear, the arguments he advanced were founded almost altogether upon the works of others, or, in some cases,

[a] Subsequent investigations have shown that the masses in which these fossils were found were but blocks or fragments in a conglomerate, itself a member of the Quebec group. Billings's conversion was, however, thorough, as shown by the following:

MONTREAL, *10th Nov., 1860.*

MY DEAR MR. MEEK:

* * * The discovery of the Point Levi fossils, and also of those published by Hall under the name of *Olenus* (from Vermont), opens out a new field in American geology. I have received several letters from Barrande on the subject. In the last one received, two days ago, he says that Angelin was then in Paris, and that he had shown him both Hall's figures and mine. Angelin agrees with him that Hall's species, and also mine from limestone No. 1, are of the Primordial type. The Quebec rocks are undoubtedly the Taconic rocks of Emmons. It will be rare sport if Emmons, after standing alone for 25 years against the majority of the *élite* (or at least those who consider themselves the élite) of American geologists, should after all be right. His unfortunate Taconic system has been annihilated and proved not to exist regularly once a year for the last twenty years, and yet it once more raises its head with a new life. I firmly believe that in the main he is right, although he may be wrong in some minor details. * * *

E. BILLINGS.

[b] The Paradoxides is a trilobite found in Sedgwick's Middle Cambrian, of England.

upon no other basis than prejudice in favor of or against certain individuals. From the time of his Pacific Railroad survey work Marcou did scarcely anything in the field, but contented himself with sitting as critic upon the work of others. For this reason he was of little actual service to American geology and his writings and opinions are not quoted in detail here, although unquestionably many of his suggestions were of value.

In 1861 there was issued the final report on the geology of Vermont by Hitchcock and A. D. Hager. On paleontological evidence the Stockbridge limestone was here set down as not older than Silurian. Cross sections showed Mounts Anthony, Equinox, Æolus, and others to have a synclinal structure, the limestone beneath and the slates above as Emmons had shown for Mount Greylock. The stratigraphy was, therefore, in favor of Emmons's view, but the paleontology was against it and no decision was reached as to the age of the quartzite.

In 1863, the year of Emmons's death, there appeared the first edition of Dana's Geology. In this the Potsdam sandstone was made to include the Primordial and the equivalent of the era of the *Paradoxides* and the Primordial beds of Scandinavia and Bohemia. The Georgia slates were also recognized as Primordial, in this conforming to the ideas of Barrande and Emmons.

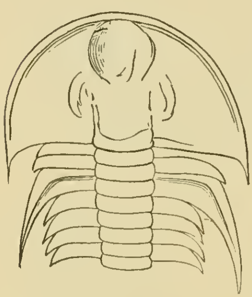


FIG. 137.—*Olenus vermontana.*

In 1869 Prof. J. B. Perry, of Vermont, entered the lists and argued in favor of the system as presented by Emmons. He was subsequently shown, through the discovery of fossils and the existence of numerous unsuspected faults and folds, to have been in error.

In 1870 the Rev. A. Wing, of Vermont, working with the avowed intention of settling the vexed question as to the age of the limestone, slates, and quartzites in the West Rutland region, found fossils in the limestone which Billings identified as probably belonging to the Chazy epoch of the Canadian (Lower Silurian) period. Still others were found, sufficient to show that the beds range from the Calciferous to and including the Trenton, and that consequently the overlying slates must be of Utica or Hudson River age, and were not limited to the Quebec group, as Logan had supposed.

In 1872 Elkanah Billings published in the Canadian Naturalist an article on the age of the black slate and red sandrock of Vermont, in which he took occasion to refer to the Taconic system and announce his views on the subject. He contended that in the consideration of this question "nearly all of the leading geologists of North America" had ranged themselves upon the wrong side; that, while for nearly a quarter of a century Doctor Emmons stood almost alone, during the last thirteen years a great revolution of opinion had come about; and that the idea that the rocks of the Taconic system were really above the Potsdam sandstone (as had been contended) had been exploded. (See letter to Meek quoted above.)

As he understood the matter at the time of writing, some of the Taconic rocks were certainly more ancient than the Potsdam, while others might be of the same age, and perhaps some of them more recent. The details, he felt, had not yet been worked out, and on account of the extremely complicated structure of the region, he ventured to say that no man at that time living would ever see a perfect map of the Taconic region. The present indications are favorable to this view of the subject.

The theory that the Taconic rocks belong to the Hudson River group, he went on to say, was an "enormous error" that originated in the geological survey of New York and thence found its way into the Canadian survey. The mistake was doubtless due to the extraordinary arrangement of the rocks, the more ancient strata being elevated and often shoved over the more recent, so that, without the aid of paleontology, it was impossible to assert positively that they were not the age of the Hudson River formation, as they appeared to be. The main object of his note was acknowledged to be, to show that while the error had originated in New York, it was corrected by the geological survey of Canada.

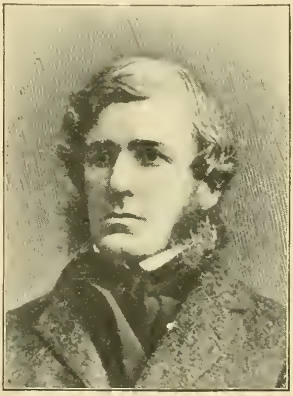


FIG. 138.—Elkanah Billings.

This article brought out a reply by J. D. Dana in the American Journal of Science for June, 1872, in which he called Billings's attention to the fact that, while he, Dana, might differ with Billings about the Taconic, the differences, after all, were not material, since Billings viewed the Taconic as developed by Emmons through successive interpolations year after year, and not as first announced in 1842. He called his attention, further, to the fact that the system was based on a section fifteen miles long, made across the Taconic Range, through Williamstown and Greylock, to North Adams on the east and to Petersburg or Berlin on the west; that the dip was originally throughout to the eastward; and that the beds were destitute of fossils and their relative age judged by superposition, according to which the Stockbridge or North Adams limestone—the most eastern rock in the section—would be the most recent.

Referring to Emmons's discovery of a fossiliferous black slate at Bald Mountain, New York, he stated that, according to Emmons's principle adopted in 1842, this slate being to the west of the Taconic, should be older than the Taconic proper, and therefore that his Taconic system was actually newer than the fossiliferous rock. This evidently being to his (Emmons's) mind impossible, he was thence led to think out a way by which rocks might dip eastward and still be newer to the westward and that, "without a fact or even an argument to sustain it, he announced in his agricultural report, published in 1843, this as the true order. He thus, by a stroke of his pen, tipped over the Taconic system and got the black slate to the top with all other Taconic rocks beneath it."

This black slate interpolation in 1843, according to Dana, thus brought mischief to the Taconic system and to much American geology and was styled by him "a most desperate blunder." Billings's work he regarded as eliminating the black slates from the system. Dana went on to state that the quartzite, which in the publication of 1842 occurred toward the middle of the section, was, in that of 1843, placed at the bottom of the Taconic series. Hence in this "perfected Taconic" the rocks which Billings had shown to be nearest to the pre-Silurian of all the Taconic beds were thus placed at the remote ends of the system, the black slate at the top and the quartzite at the bottom, the former being of Primordial age and the only rock series which had yet proven to be pre-Potsdam.

Dana acknowledged that Emmons was deserving of honor for combating the old idea which had prevailed among geologists and paleontologists, to the effect that the Taconic slates belong to the Hudson River period; yet he contended that he "blundered in everything else," determining nothing correctly as regarded the age or order of succession of the rocks of the system, and "his assumptions after 1842 were so great as to order of stratification and faults, and his way of sweeping distant rocks into his system so unscientific, that his opponents had abundant reasons for their doubts." He went on to say that no one knew, even at that date, what the precise age of the slates of the Taconic Mountains might be, although Logan's view that they belong to the Quebec seemed nearest the truth. The only way, he argued, for geologists to get out of the Taconic perplexity was to go back to Emmons's original report and section of 1842. "The name Taconic," he wrote, "belongs only to the era represented by the rocks of the Taconic Mountain," and nowhere else.

In a series of articles in the American Journal of Science, beginning with December of 1872, Dana showed the conformability of the Taconic slates and schists of the Taconic Mountains and the Stockbridge limestone and quartzite, and on the basis of the discoveries of Wing and Billings, pronounced the limestone to be of Trenton and Chazy age and the schists and slates to be of Hudson River age, in this agreeing with Rogers. He also pointed out that the same beds of metamorphic rocks might vary as do their unconsolidated representatives, being quartzite in one part and mica-schist or even gneiss elsewhere, and hence that purely lithological evidence as to the identity of beds was practically worthless. This is a little amusing as coming from Dana, who himself accepted the presence of the mineral chondrodite in the limestones of Berkshire as evidence of the Archean age.

In 1878, T. Nelson Dale found brachiopods belonging to the Hudson River group in the Taconic slates at Poughkeepsie. In this same year W. B. Dwight began work in the "Sparry limestone" of Dutchess County, New York, finding fossils of undoubted Lower Silurian age.[a] These finds and others made by S. W. Ford and I. P. Bishop in adjacent localities were made use of by Professor Dana in his subsequent papers.

Dana continued in the field at intervals until 1889, accepting as his working basis the Chazy fossils found by Doctor Wing at West Rutland, and accompanying and working conjointly with Wing throughout the period. In 1879 he showed on stratigraphic and fossiliferous evidence that the Taconic schists, so called, as developed in Dutchess and adjacent counties, were of the age of the Hudson River group, and the five limestone belts there found, but five successive outcroppings of the Lower Silurian limestone brought to the surface by a series of flexures. In this he agreed in the main with Mather.

In 1884, Hall for the first time put himself fully on record as opposed to the Taconic system on stratigraphic as well as paleontological grounds. In this year he sent Dana copies of two sections of the Taconic area and manuscript notes claimed by him to have been made prior to 1845, and which gave the result of his own studies. In these Mounts Anthony and Equinox are shown to have a synclinal structure, the limestone underlying a broad synclinal of slates and schists, the former being put down as Trenton and lower, while the slates and schists were of Hudson River age. Prompt publication would have given Hall priority over the Vermont survey and others, but owing to the long delay the matter is of only historical interest.

In Volumes XXIX and XXXIII (1885 and 1887) of the American Journal of Science, Dana again takes up the subject systematically under the caption of Taconic Rocks and Stratigraphy, the paper being accompanied by a map of the region and numerous sections. He showed that the flexures throughout the Taconic area were of a prevailing synclinal habit; that the limestone was a continuous formation lying underneath the mountains and was overlaid conformably by strata of quartzite and quartzitic and ordinary mica schist, and underlaid along the eastern border by quartzite and mica schist also. He further showed that within the Taconic region the texture and mineral nature of the limestone beds varied geographically, the crystalline texture being coarser to the southward and eastward. He found no evidence

[a] Dwight later found Cambrian fossils in these same rocks.

of general overthrust faulting affecting the entire region. As to the age of the rocks he remained conservative, but still regarded the limestone as beyond doubt Lower Silurian, though whether Trenton, Chazy, or Calciferous remained an open question.

In the Journal for 1886 he referred again to the matter, questioning the reliability of the lithological evidence put forth by Emmons as to the identity of his Taconic rocks and those of Sedgwick's Cambrian, asserting that "geological investigation with reference to the Cambrian had not advanced so far as to make its application safe." In this paper he reported also the finding in Canaan, New York, of Lower Silurian fossils in Sparry limestone, this being the oldest stratum of the Taconic system, as announced by Emmons in 1842. These fossils were sliced and studied by Professor Dwight, of Poughkeepsie, and S. W. Ford, and identified as belonging probably to the Trenton period.

In 1886, C. D. Walcott, then paleontologist of the U. S. Geological Survey, took up the subject, giving a summary of his results, with map, in the American Journal of Science of April and May, 1888. Walcott began with a systematic study of the slates, limestones, and quartzites of Vermont and the adjoining counties of New York, continuing his work the following season and paying particular attention to areas within the counties of Washington and Rensselaer, New York; Bennington, Vermont; and Berkshire, Massachusetts, since here were found the series of sections described by Emmons and nearly all the localities mentioned by him.

Fig. 139.—Charles Doolittle Walcott.

Mr. Walcott showed to his own satisfaction and that of most of those having any detailed knowledge of the subject that the quartzite series belong to the Middle Cambrian, the talcose slates to the Upper Cambrian, the limestones to the Calciferous,[a] Chazy, and Trenton, and the slates and sandstones to the Hudson River group. He agreed mainly with Emmons in his lithological descriptions and the general dip and arrangement of the strata, but disagreed with him in his identification of the geological age of the formations of the Lower Taconic, the stratigraphic relations of his Lower and Upper Taconic, and also as to the value of the stratigraphic and paleontological identifications of age. He showed that the granular quartz, supposed by Emmons to be unfossiliferous and to lie at the base of his Taconic system, was actually fossiliferous and the equivalent of the greater portion of the

[a] The supposed Middle Cambrian and a part of the Calciferous here described were subsequently relegated to the Lower Cambrian.

Upper Taconic;[a] also that this quartzite was a shore deposit formed at the same time as were the silico-calcareous muds in deeper waters, and which Emmons had included in his Upper Taconic. The Stockbridge limestone, which Emmons had regarded as a peculiar pre-Silurian deposit, he showed on paleontological evidence to be the equivalent of the Trenton, Chazy, and Calciferous limestones of the Lower Silurian,[b] while the Talcose slate resting conformably upon the Stockbridge limestone was found to contain graptolites of Hudson River age. Emmons's subdivision of Upper Taconic he regarded as merely due to a repetition of certain beds brought up by an overthrust fault, as shown in fig. 140.

Walcott in his summary of the paleontological evidence relative to the Taconic, stated: (1) The trilobites described by Emmons in 1844–

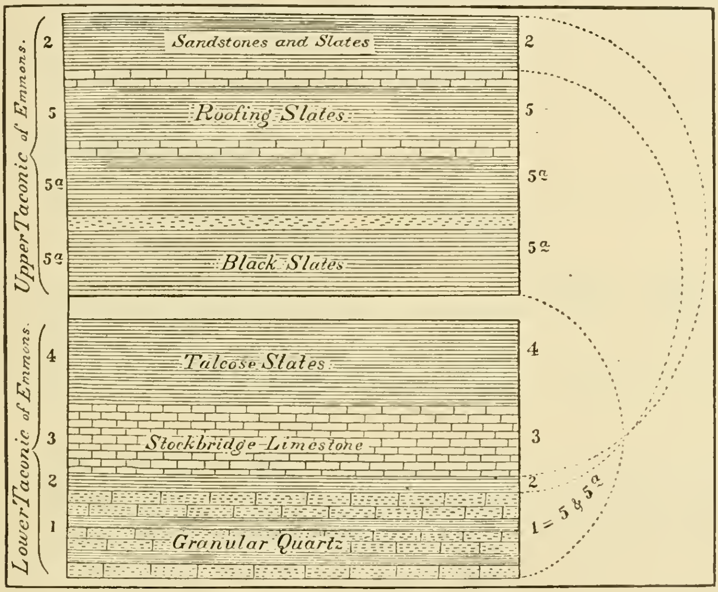


FIG. 140.—Tabular view of Taconic Strata as arranged by E. Emmons. (After C. D. Walcott.)

1847 from the black slate were referred then to the highest member of the Taconic system on stratigraphic evidence; but (2) in 1856 were, on evidence of the same kind, referred to the lowest member.[c] (3) That in 1859 they were referred to a pre-Potsdam position[d] by comparison with a fauna whose position had been stratigraphically determined with relation to the Silurian fauna. Further, (4) that the

[a] These are now accepted as basal Lower Cambrian.

[b] But, later, Foerste and Wolff found Lower Cambrian forms near the base of these rocks at Rutland, Vermont.

[c] Subsequent studies seem to show that Emmons was correct in this.

[d] They are to-day referred to the Lower Cambrian.

Nereites and other trails which Emmons regarded as typical for the Taconic had not yet been stratigraphically located, while (5) the graptolites formed part of the fauna of the Hudson terrane.

Emmons's errors, according to Mr. Walcott, were due almost wholly to his trust in lithological characters; his supposed unconformity between the Taconic and Champlain systems was based primarily on the similarity in lithologic characters of the Calciferous sand rock of the Lower Silurian, and the Calciferous sand rock of what is now known, from its fossils, to be a part of his upper Taconic; also that he confused the dark shales of the Lower Silurian with those of his upper Taconic and failed to recognize the obvious fact that the Calciferous terranes were frequently represented in geological sections by a shale undistinguishable from that of the Hudson River; and that in several places the Trenton limestone is replaced by shale. According to T. N. Dale, Emmons was also in error in assuming that the slates along the east foot of the Taconic range dipped to the east, he having confused cleavage with bedding.

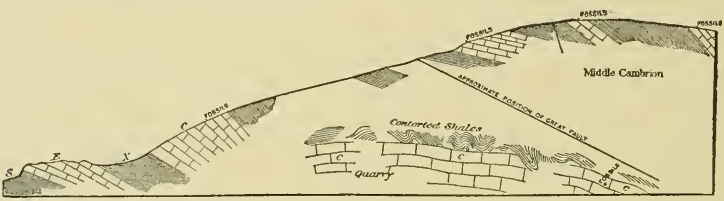


FIG. 141.—Section of Bald Mountain from the south. The profile of the mountain and position of the Cambrian and Lower Silurian rocks are taken from a photograph. The "Upper Taconic" = Cambrian slate, sandrock and limestone are shown to the right of the fault, and *c*=Chazy limestone; *x*=dark shales, interbedded between *c* and the Calciferous sandrock, E; *s*=dark argillaceous shales beneath the Calciferous sandrock. (After C. D. Walcott.)

At the eighth meeting of the American Committee of the International Geological Congress, which was held in New York in April, 1888, the subject of the subdivision and nomenclature of the American Paleozoic formations was discussed, and incidentally the matter of using the name Taconic, and its limitations, if used at all, was pretty thoroughly gone over. A considerable diversity of opinion was found to exist; although the committee at first reported in favor of retaining the name, they were apparently subsequently led to change their views upon the presentation of new evidence by Mr. Walcott. A brief summary of some of the views adopted is given below.

Dana objected to the retention of the name, thinking it would be regarded only as "a reminder of Emmons's blundering work—a succession of unstudied assumptions that brought only evil to the science." S. W. Ford favored the adoption of the name Taconic for the middle portion of the Cambrian, as the term was then used, or that marked by the presence of the fossil *Olenellus*. Hall felt that it might be well to retain the name for those rocks lying below the Potsdam, while C. H. Hitchcock considered the lowest Taconic as of lower Potsdam age.

Newberry, on the other hand, would retain the name Taconic as a group name for one of the minor subdivisions of the Upper Cambrian, while Alexander Winchell, from a perusal of the literature only, would retain the name for those rocks underlying the Cambrian and retaining the primordial fauna (*Paradoxides*). The Canadian geologists, Dawson and Selwyn, both regarded the term as useless and unnecessary, while H. S. Williams and Joseph Le Conte recommended that it be dropped entirely, owing to the existing conflict of opinion.

The committee recommended that all the strata lying between the Devonian and Archean be divided into three great groups, the Silurian, Cambrian, and Taconic, the last named to be subdivided as below:

TACONIC.

Faunal (systematic) designations.		Rock masses of New York and New England. Stratigraphic designations.
Taconic-Primordial or First Fauna.	Sub-Faunas.	
	St. Croix.	Lower portion of the Calciferous sand rock of New York. The St. Croix beds (so-called western Potsdam) of the Mississippi Valley.
	Taconic.	The Georgia group. The Taconic black slate and granular quartz.
	Acadian.	Paradoxides beds of Braintree, Massachusetts, and St. John's group of New Brunswick.

As above noted, this report of the committee was not adopted, and it is probably due more to the work of Dana and Walcott than to all others that the term to-day finds no place except historically in American geology.

As to the justice of this decision, there may be some question, particularly when one recalls the fact that Mr. Walcott's own studies later showed the existence of his *Olenellus* (Georgian) fauna *below* rather than above the *Paradoxides* (Acadian) beds.

When one considers further the condition of the science at the time Emmons first proposed the system and the conditions under which he labored, without satisfactory maps, it is obviously unfair to hold him to as strict an account as would be justifiable with reference to the later workers. Even were it true, as stated, that there is to-day "*no known stratum of rock in the Taconic range*" that is of the geological age assigned it by Doctor Emmons,[a] and even though it were also true

[a] Emmons's granular quartz and the lower part of the Stockbridge limestone are to-day regarded as older than the Potsdam, as a part of the Lower Cambrian.

that "all his reasons for calling the Hudson terrane *Taconic* were based on errors of stratigraphy, and it was only a fortunate happening that any portion of the upper Taconic rocks occur where he placed them in his stratigraphic scheme," still there would, to the unprejudiced, seem to be abundant room for the recognition of the name, a fact which Mr. Walcott has himself recognized by the adoption of the borrowed term Ordovician. Moreover, ruling out the term on the ground of blundering is scarcely just, since, as Winchell pertinently remarks, a similar ruling would take from Columbus the credit of having discovered America, since he blundered upon it, expecting to strike India.

The following tables illustrate the three principal stages of the Taconic controversy up to 1903, in the columns to the left the subdivisions of Emmons being given, and in those to the right the equivalents as recognized by Dana and other authorities.

Taconic of 1842.	Equivalents of 1888.	Equivalents of 1903.
6. Stockbridge limestone	II. Lower Silurian	Upper part Lower Silurian. Lower part Lower Cambrian.
5. a. Magnesian slate of Greylock, perhaps a repetition of No. 3.	III. Hudson slates	Lower Silurian.
5. b. Granular quartz	I. Cambrian	Lower Cambrian.
4. Limestone	II. Lower Silurian	Lower Cambrian.
3. Magnesian slate of Taconic Mountains.	III. Hudson slates	Lower Silurian.
2. Sparry limestone	II. Lower Silurian	Upper part Lower Silurian; lower part Lower Cambrian.
1. Taconic slate	III and I. Hudson slates and Cambrian.	Lower Silurian.
Taconic of 1844.		
5. a. Bald Mountain black slate.	I. Cambrian	Lower Cambrian.
5. b. Taconic slate	III and I. Hudson slates and Cambrian.	Lower Silurian.
4. Sparry limestone	II. Lower Silurian	Upper part Lower Silurian; lower part Lower Cambrian.
3. Magnesian slate	III. Hudson slates	Lower Silurian.
2. Stockbridge limestone	II. Lower Silurian	Upper part Lower Silurian; lower part Lower Cambrian.
1. Granular quartz	I. Cambrian	Lower Cambrian.
Taconic of 1855.		
Upper Taconic. 2. Bald Mountain black slate.	I. Cambrian	Lower Cambrian.
Upper Taconic. 1. Taconic slate	III and I. Hudson slates and Cambrian.	Lower Silurian.
Lower Taconic. 3. Magnesian slate	III. Hudson slates	Lower Silurian.
Lower Taconic. 2. Stockbridge limestone.	II. Lower Silurian	Upper part Lower Silurian; lower part Lower Cambrian.
Lower Taconic. 1. Granular quartz	I. Cambrian	Lower Cambrian.

APPENDIX A.

TABLES SHOWING THE GRADUAL DEVELOPMENT OF THE GEOLOGICAL COLUMN, AS GIVEN IN THE PRINCIPAL TEXT-BOOKS.

Development of Geological Column.

Maclure, 1817. (Wernerian.)		Eaton, 1820.	
Class IV. Alluvial rocks	1. Peat. 2. Sand and gravel. 3. Loam. 4. Bog iron ore. 5. Nagel-fluh. 6. Calc tuff. 7. Calc sinter.	V. Alluvial class	18. Alluvian. 17. Geest.
Class III. Floetz or secondary rocks	12. Newest floetz trap formation. 11. Independent coal formation. 10. Floetz trap formation. 9. Chalk formation. 8. Rock salt formation. 7. Third floetz sandstone. 6. Second floetz sandstone. 5. Second floetz gypsum. 4. Second or variegated sandstone. 3. First or oldest floetz gypsum. 2. First or oldest floetz limestone. 1. Old Red Sandstone or first sandstone formation.	IV. Superincumbent class.	16. Greenstone trap. 15. Basalt.
		III. Secondary class.	14. Secondary sandstone. 13. Gypsum. 12. Compact limestone. 11. Breccia.
Class II. Transition rocks	5. Transition gypsum. 4. Transition flinty slate. 3. Graywacke. 2. Transition trap. 1. Transition limestone.	II. Transition class.	10. Redsandstone. 9. Graywacke. 8. Metalliferous limestone. 7. Argillite.
Class I. Primitive rocks	14. White limestone. 13. Primitive gypsum. 12. Primitive flint. 11. Quartz rock. 10. Topaz rock. 9. Syenite. 8. Porphyry. 7. Serpentine. 6. Primitive trap. 5. Primitive limestone. 4. Clay slate. 3. Mica slate. 2. Gneiss. 1. Granite.	I. Primitive class.	6. Granular limestone. 5. Talcose rock. 4. Mica slate. 3. Hornblende rock. 2. Gneiss. 1. Granite.

The position of the volcanic productions was problematical, but it was thought they might belong to the superincumbent class.

Development of Geological Column—Continued.

Conybeare and Phillips, 1822. (English.)		
Superior order	Alluvial, diluvial. Regular strata above the chalk, including upper marine (Suffolk crag, Bagshot sands) fresh-water formations. London clays, plastic clays, and sands.	
Supermedial order.	Chalk. Chalk marl. Greensand. Weald clay.	
	Upper Oolite division.	Purbeck beds. Portland oolite. Kimmeridge clay.
	Middle Oolite division.	Coral rag. Oxford crag.
	Lower Oolite division.	Cornbrash. Stonefield slate. Forest marble. Great Oolite.
	Lias. New Red Sandstone. Magnesian limestone.	
Medial or carboniferous order.	Coal Measures. Millstone grit and shale. Carboniferous or Mountain limestone. Old Red Sandstone.	

Eaton, 1830.	
Anomalous deposits	IV. Analluvian. III. Post-Diluvion. II. Diluvion. I. Volcanic.
Class V. Tertiary or fifth series.	23. Shell marl. 22. Marine sand and crag. 21. Marly clay. 20. Plastic clay.
Class IV. Upper Secondary or fourth series.	19. Oolitic rocks. 18. Third graywacke.
Class III. Lower Secondary or third series.	17. Corniferous limestone. 16. Geodiferous limestone. 15. Lias. 14. Ferriferous rock. 13. Saliferous rock. 12. Second graywacke.
Class II. Transition or second series.	11. Metalliferous limerock. 10. Calciferous sand rock. 9. Sparrylime rock. 8. First graywacke. 7. Argillite.
Class I. Primitive or first series.	6. Granular limestone. 5. Granular quartz. 4. Talcose slate. 3. Hornblende rock. 2. Mica slate. 1. Granite.

Development of Geological Column—Continued.

De La Beche, 1832.

Stratified rocks.	Superior stratified, or fossiliferous.	1. Modern group	Detritus such as is produced by causes now in action, as coral islands, travertine, etc.
		2. Erratic block group.	Transported bowlders and blocks; gravel on hills and plains apparently produced by greater forces than those now in action.
		3. Superior Cretaceous group.	Various deposits above the chalk, such as the Crag, Isle of Wight beds, London plastic clay, etc.
		4. Cretaceous group.	1. Chalk. 2. Upper Greensand. 3. Gault. 4. Lower Greensand. 1. Weald clay. 2. Hastings sands. 3. Purbeck beds.
		5. Oolitic group.	Oolite and Lias.
		6. Red Sandstone group.	1. Variegated or red marl. 2. Muschelkalk. 3. Red sandstone. 4. Zechstein. 5. Red conglomerate.
		7. Carboniferous group.	1. Coal Measures. 2. Carboniferous limestone. 3. Old Red Sandstone.
		8. Graywacke group.	Graywacke, graywacke limestone, graywacke clay slate, etc.
		9. Lowest Fossiliferous group.	Various slates, frequently mixed with stratified compounds resembling those of unstratified rocks.
	Inferior stratified; nonfossiliferous.	No determinate order of superposition.	Various schistose rocks and crystalline stratified compounds in gneiss, protogene, etc.
Unstratified rocks.		Volcanic, trappean, serpentinous, and granitic rocks.	Ancient and modern lava, trachyte, basalt, greenstone, corneans, augite, and hornblende porphyries, serpentine, diallage rock, sienite, quartziferous poryhyry, granite, etc.

Lyell, 1837.

I. Recent period.	A	Consolidated sands and gravels. Delta formations, etc.
II. Tertiary period.	B. Newer Miocene.	Marine and fresh-water sands, clays, limestones, etc.
	C. Older Pliocene.	Subappenine marl, English crag, marine and fresh water.
	D. Miocene	Faluns of Loire, etc. Marine and fresh water.
	E. Eocene	Calcaire Grossier, etc., London clays, sands, etc., marine and fresh water.
III. Secondary period.	F. Cretaceous group.	1. Maestricht beds. 2. Chalk with flints. 3. Chalk without flints. 4. Upper Greensand. 5. Gault. 6. Lower Greensand.
	G. Wealden group.	1. Weald clay. 2. Hastings sands. 3. Purbeck beds.
	H. Oolitic or Jura limestone group.	1. Portland beds. 2. Kimmeridge clays. 3. Coral rag. 4. Oxford clay. 5. Cornbrash. 6. Forest marble. 7. Great Oolite. 8. Fuller's earth. 9. Inferior Oolite.
	I. Lias group	Lias.
	K. New Red sandstone group.	1. Keuper. 2. Muschelkalk. 3. Bunter sandstone.
	L. Magnesian limestone group.	1. Magnesian limestone and Zechstein of Germany. 2. Red conglomerate.
	M. Carboniferous group.	1. Coal Measures. 2. Mountain limestone.
	N. Old Red Sandstone group.	1. Old Red Sandstone.
IV. Transition period.	O. Silurian group.	1. Ludlow beds. 2. Wenlock limestone. 3. Caradoc sandstone. 4. Llandeilo flags.
	P	Rocks older than the Silurian, graywacke, etc.
	Primary rocks.	

Development of Geological Column—Continued.

New York State survey, 1841–1843.

VIII. Quaternary system.		
VII. Tertiary system.		
VI. New Red Sandstone.		
V. Carboniferous system.		
IV. Old Red Sandstone.		
III. New York system.	Erie division	28. Chemung group. 27. Portage group. 26. Genesee group. 25. Tully limestone. 24. Hamilton group. 23. Marcellus shale.
	Helderberg division.	22. Corniferous limestone. 21. Onondaga limestone. 20. Schoharie grit. 19. Cauda galli grit. 18. Oriskany sandstone. 17. Upper Pentamerous limestone. 16. Encrinal limestone. 15. Delthyris shaly limestone. 14. Pentamerous limestone. 13. Waterlime group. 12. Onondaga salt group.
	Ontario division.	11. Niagara group. 10. Clinton group. 9. Medina sandstone.
	Champlain division.	8. Oneida, or Shawangunk conglomerate. 7. Gray sandstone. 6. Hudson River group. 5. Utica slate. 4. Trenton limestone. 3. Black River limestone. 2. Calciferous sandstone. 1. Potsdam sandstone.
II. Taconic system.		
I. Primary or Hypogene system.		

Ansted, 1844.

Tertiary period	Superficial or Pleistocene deposits.	Diluvium and alluvium.
	Newer Tertiary or Pliocene.	Till.
	Middle Tertiary or Miocene.	Red crag or coralline crag.
	Older Tertiary or Eocene.	Bagshot sand. London clay.
Newer secondary period.	Cretaceous system.	Upper chalk. Lower chalk. Chalk marl. Upper Greensand. Gault. Lower Greensand.
Middle secondary period.	Wealden formation.	Wealden clay. Hastings sand. Purbeck beds.
	Upper Oolitic system.	Portland stone. Portland sand. Kimmeridge clay.
	Middle Oolitic system.	Upper calc grit. Coral rag. Lower calc grit. Oxford clay. Kelloway rock.
	Lower Oolite	Cornbrash. Forest marble. Great Oolite. Stonesfield slate. Inferior Oolite. Calcareous sand.
	Liassic group	Upper Lias shale. Lower Lias shale. Lower Lias limestone.
Older secondary period.	Upper New Red Sandstone or Triassic system.	Keuper. Muschelkalk. Bunter sandstein.
Newer Paleozoic system.	Magnesian limestone or Permian system.	Magnesian limestone. Lower New Red Sandstone.
	Carboniferous system.	Upper coal grit. Coal Measures. Millstone grit. Carboniferous limestone. Lower Carboniferous shales.
Middle Paleozoic system.	Devonian system or Old Red Sandstone.	Slates and limestones of Devonshire, conglomerates, cornstone, and tilestone.
Older Paleozoic system.	Upper Silurian rocks.	Ludlow and Wenlock series, and Upper Cambrian and Cambrian rocks.
	Lower Silurian rocks.	Caradoc sandstone and Llandeilo flags, Older Cambrian and Cambrian fossiliferous shales.

Development of Geological Column—Continued.

De La Beche, 1851.

Tertiary or Cainozoic.	A. Upper Tertiary	*a.* Mineral accumulations of the present time.
		b. Pleistocene.
		c. Pliocene.
	B. Middle Tertiary.	*a.* Miocene.
	C. Lower Tertiary.	*a.* Eocene.
Secondary or Mesozoic.	A. Cretaceous group.	*a.* Chalk or Maestricht of Denmark.
		b. Ordinary chalk, with or without flints.
		c. Merstham beds, or Upper Greensand.
		d. Gault.
		e. Shanklin sands, Neocomian, or Lower Greensand.
	B. Marine equivalents of Cretaceous group.	*a.* Wealden.
		b. Hastings sands.
		c. Purbeck beds.
	C. Jurassic or Oolitic group.	*a.* Portland or Oolitic limestone.
		c. Portland sands.
		d. Kimmeridge clay.
		e. Coral rag.
		f. Oxford clay.
		g. Cornbrash.
		h. Forest marble.
		i. Fuller's earth.
		k. Inferior Oolite.
		l. Lias (Upper and Lower).
	D. Trias group	*a.* Variegated marls.
		b. Muschelkalk.
		c. Red Sandstone (Bunter, etc.).
Primary or Paleozoic.	A. Permian group	*a.* Zechstein.
		b. Rothe todte liegende.
	B. Marine equivalents of.	*a.* Coal Measures.
	C. Carboniferous limestone group.	*a.* Carboniferous and Mountain limestone, etc.
		b. Carboniferous slates.
	D. Devonian group.	*a.* Various modifications of Old Red Sandstones.
	E. Silurian group	*a.* Upper.
		b. Middle.
		c. Lower.
	F. Cambrian	Various rocks subjacent to the Silurian series in Wales and Ireland and above the mica and chlorite slates, etc.

Lyell, 1855.

	Post Tertiary	1. Recent.
		2. Post Pliocene.
Tertiary or Cainozoic.	Pliocene	3. Newer Pliocene.
		4. Older Pliocene.
	Miocene	5. Miocene.
	Eocene	6. Upper Eocene.
		7. Middle Eocene.
		8. Lower Eocene.
Secondary or Mesozoic.	Cretaceous	9. Maestricht beds.
		10. Upper white chalk
		11. Lower white chalk
		12. Upper Greensand.
		13. Gault.
		14. Lower Greensand.
		15. Wealden.
	Jurassic	16. Purbeck beds.
		17. Portland stone.
		18. Kimmeridge clay.
		19. Coral rag.
		20. Oxford clay.
		21. Great or Bath Oolite.
		22. Inferior Oolite.
		23. Lias.
	Triassic	24. Upper Trias.
		25. Middle Trias or Muschelkalk.
		26. Lower Trias.
Primary or Paleozoic.	Permian	27. Permian or magnesian limestone.
	Carboniferous	28. Coal Measures.
		29. Carboniferons limestone.
	Devonian	30. Upper Devonian.
		31. Lower Devonian.
	Silurian	32. Upper Silurian.
		33. Lower Silurian.
	Cambrian	34. Upper Cambrian.
		35. Lower Cambrian.

Development of Geological Column—Continued.

Phillips, 1855.

Tertiary or Cainozoic series.		Post-Glacial. Glacial. Pre-Glacial. Crag. Fluvio-Marine. London clay. Plastic clay.
Secondary or Mesozoic series.	U. Mesozoic.	Chalk. Greensand.
	L. Mesozoic.	Wealden. Upper Oolite. Middle Oolite. Lower Oolite. Lias. Poikilitic series.
Primary or Paleozoic series.	U. Paleozoic.	Permian. Coal series. Mountain limestone.
	M. Paleozoic.	Old Red, or Devonian series.
	L. Paleozoic.	Ludlow. Wenlock. Caradoc. Llandeilo. Festiniog. Bangor.
Hypozoic series.		
Mica schist, including chlorite schist, talc schist, quartz rock, granular limestone, etc. Gneiss, including limestone, hornblende schist, etc. Granitic rocks which are not stratified usually form the basis of the strata, and are frequently, but not by any means universally, followed by the gneiss and mica slate.		

Dana, 1862.

Age of Man.		Post-Tertiary		Pleistocene or Post-Tertiary.
		Tertiary		Pliocene. Miocene. Eocene.
Reptilian age.	Cretaceous.			Upper Cretaceous. Middle Cretaceous. Lower Cretaceous.
		Wealden		Wealden.
	Jurassic.	Oolitic epoch		Upper Oolitic: Purbeck, Portland, and Kimmeridge clays. Middle Oolitic: Coral rag. Oxford clay. Lower Oolitic: Stonefield. Inferior Oolite.
		Liassic epoch		Upper Lias. Middle Lias. Lower Lias.
	Triassic.			Keuper. Muschelkalk. Buntersandstone.
Carboniferous age.		Permian	15	Permian.
		Carboniferous	14*c* 14*b* 14*a*	Upper Coal Measures. Lower Coal Measures. Millstone grit.
		Subcarboniferous	13*b* 13*a*	Upper. Lower.
Devonian age, or Age of Fishes.		Catskill	12	
		Chemung	11*b* 11*a*	Chemung. Portage.
		Hamilton	10*c* 10*b* 10*a*	Genesee. Hamilton. Marcellus.
		Upper Helderberg	9*c* 9*b* 9*a*	Upper Helderberg. Schoharie. Cauda-galli.
		Oriskany	8	Oriskany.
Silurian, or Age of Mollusks.	Upper Silurian.	Lower Helderburg	7	Lower Helderberg.
		Salina	6	Saliferous.
		Niagara	5*d* 5*c* 5*b* 5*a*	Niagara. Clinton. Medina. Oneida.
	Lower Silurian.	Hudson	4*b* 4*a*	Hudson River. Utica.
		Trenton	3*b* 3*a*	Trenton. Black River. Birdseye. Chazy.
		Potsdam	2*b* 2*a*	Calciferous. Potsdam.
		Azoic	1	Azoic.

Development of Geological Column—Continued.

Dana, 1875–1879.

Age	Period	Division	No.	Subdivisions
Age of Man, or Quaternary.		Post-Tertiary		Pleistocene or Post-Tertiary
		Tertiary		Pliocene. Miocene. Eocene.
Reptilian age.	Cretaceous.			Upper Cretaceous. Middle Cretaceous. Lower Cretaceous.
		Wealden		Wealden.
	Jurassic.	Oolitic epoch		Upper Oolite. Purbeck, Portland, and Kimmeridge clays. Middle Oolite. {Coral rag. Oxford clay.} Lower Oolite. {Stonesfield. Inferior Oolite.}
		Liassic epoch		Upper Lias. Middle Lias. Lower Lias.
	Triassic.			Keuper. Muschelkalk. Buntersandstone.
Carboniferous age.		Permian	15	Permian.
		Carboniferous	14*c* 14*b* 14*a*	Upper Coal Measures. Lower Coal Measures. Millstone grit.
		Subcarboniferous	13*b* 13*a*	Upper. Lower.
Devonian, or Age of Fishes.		Catskill	12	
		Chemung	11*b* 11*a*	Chemung. Portage.
		Hamilton	10*c* 10*b* 10*a*	Genesee. Hamilton. Marcellus.
		Corniferous	9*c* 9*b* 9*a*	Corniferous. Schoharie. Cauda-galli.
Silurian, or Age of Invertebrates.	Upper Silurian.	Oriskany	8	Oriskany.
		Lower Helderberg	7	Lower Helderberg.
		Salina	6	Salina.
		Niagara	5*c* 5*b* 5*a*	Niagara. Clinton. Medina.
	Lower Silurian.	Trenton	4*c* 4*b* 4*a*	Cincinnati. Utica. Trenton.
		Canadian	3*c* 3*b* 3*a*	Chazy. Quebec. Calciferous.
		Primordial or Cambrian	2*b* 2*a*	Potsdam. Acadian.
Archean			1	Archean.

Development of Geological Column—Continued.

Dana, 1895.

					Dana, 1895
Cenozoic time.		Mammalian era.	Quaternary		Recent. Champlain. Glacial.
Cenozoic time.		Mammalian era.	Tertiary		Pliocene. } Neocene. Miocene. } Neocene. Eocene.
Mesozoic time.		Cretaceous.	Upper Cretaceous		Upper Cretaceous.
Mesozoic time.		Cretaceous.	Lower Cretaceous		Lower Cretaceous.
Mesozoic time.		Jurassic.	Upper, or Portlandian epoch Middle, or Oolitic epoch		Upper Oolite. Middle Oolite. Lower Oolite.
Mesozoic time.		Jurassic.	Lower, or Liassic epoch		Upper Lias. Marlstone. Lower Lias.
Mesozoic time.		Triassic.	Upper Middle Lower		Keuper. Muschelkalk. Buntersandstein.
Paleozoic time.	Neopaleozoic section.	Carbonic era.	Permian	14	Permian.
Paleozoic time.	Neopaleozoic section.	Carbonic era.	Carboniferous	13*c* 13*b* 13*a*	Upper Coal Measures. Lower Coal Measures. Millstone grit.
Paleozoic time.	Neopaleozoic section.	Carbonic era.	Subcarboniferous	12*b* 12*a*	Upper, or Mauch Chunk. Lower, or Pocono.
Paleozoic time.	Neopaleozoic section.	Devonian era.	Upper Devonian	11*b* 11*a*	Chemung and Catskill. Portage, Genesee.
Paleozoic time.	Neopaleozoic section.	Devonian era.	Middle Devonian or Hamilton	10*b* 10*a*	Hamilton. Marcellus.
Paleozoic time.	Neopaleozoic section.	Devonian era.	Corniferous	9*b* 9*a*	Corniferous. Schoharie and Cauda-galli.
Paleozoic time.	Neopaleozoic section.	Devonian era.	Oriskany	8	Oriskany.
Paleozoic time.	Neopaleozoic section.	Upper Silurian era.	Lower Helderberg	7	Lower Helderberg.
Paleozoic time.	Neopaleozoic section.	Upper Silurian era.	Onondaga	6	Salina and waterlime.
Paleozoic time.	Neopaleozoic section.	Upper Silurian era.	Niagara	5*c* 5*b* 5*a*	Niagara. Clinton. Medina.
Paleozoic time.	Eopaleozoic section.	Lower Silurian era.	Trenton	4*c* 4*b* 4*a*	Hudson. Utica. Trenton.
Paleozoic time.	Eopaleozoic section.	Lower Silurian era.	Canadian	3*c* 3*a*	Chazy. Calciferous.
Paleozoic time.	Eopaleozoic section.	Cambrian era.	Upper Middle Lower	2*c* 2*b* 2*a*	Potsdam. Acadian. Georgian.
Archean				....	Huronian. Laurentian.

APPENDIX B.

BRIEF BIOGRAPHICAL SKETCHES OF THE PRINCIPAL WORKERS IN AMERICAN GEOLOGY.

Appendix B.

BRIEF BIOGRAPHICAL SKETCHES OF THE PRINCIPAL WORKERS IN AMERICAN GEOLOGY.

Adams, Charles Baker. Conchologist and geologist.

Born in Dorchester, Mass., January 11, 1814; died in St. Thomas, West Indies, January 18, 1853. Graduated at Amherst in 1834, and took up study of theology at Andover, leaving there to join E. Hitchcock on geological survey of New York. Professor of chemistry and natural history in Middlebury College, Vermont, 1838-1847. State geologist of Vermont, 1845–1848. In 1847 accepted professorship of zoology and astronomy at Amherst. Failing health took him to West Indies, where he died. Assisted greatly in making known the mollusk-fauna of Panama and West Indies.

Biogr. Wm. H. Dall. Some American Conchologists, Proc. Biolog. Soc. of Washn., IV, 1886–88, pp. 112–116.
H. M. Seeley, Amer. Geol., XXXII, No. 1, July, 1903, pp. 1–12.
Thos. Bland, Amer. Jour. of Conchology, 1, pp. 191–204. 1865.

Agassiz, Jean Louis Rodolphe. Zoologist and glacialist.

Born in Motier, Switzerland, May 28, 1807; died in Cambridge, Mass., December 14, 1873. In 1832, professor in the Academy of Neuchatel. In 1846, came to United States and in 1847, appointed professor of zoology and geology in Harvard University. In 1851, professor of comparative anatomy in Charleston, S. C. In 1859, founded in Cambridge the Museum of Comparative Zoology. Best known as a lecturer, teacher, and authority on fossil fishes, and as the father of the glacial theory. His Études sur les Glaciers appeared in 1840 and his Glacial System in 1847.

Biogr. Life and Correspondence, by Elizabeth C. Agassiz, Boston, 1886.
Biogr. Life and Letters of Louis Agassiz, by Jules Marcou, Boston, 1895.
Memoir of Louis Agassiz, by Arnold Guyot. Biog. Mems. Nat. Acad. Sci., II, 1886.
Richard Bliss, Pop. Sci. Monthly, IV, March, 1874, pp. 608–618.

Akerly, Samuel. Physician.

Born ———, 1785; died on Staten Island, New York, July 6, 1845. Graduated from Columbia College, 1804. Wrote mainly on medical subjects. His principal geological publication was an essay on the geology of the Hudson River.

Aldrich, Truman Heminway.

Born in Palmyra, N. Y., October 17, 1848. Graduated at the Rensselaer Polytechnic Institute, Troy, N. Y., as a mining and civil engineer, in 1869. Assistant engineer on various railroad surveys and public works in New Jersey till 1871, when he moved to Alabama and became interested in coal mining. His publications are mainly on coal and recent shells and Tertiary fossils.

Alger, Francis.

Born in Bridgewater, Mass., March 8, 1807; died in Washington, D. C., November 27, 1863. In 1826–27, made collecting trips into Nova Scotia, and in 1828–29, explored in the same Province with C. T. Jackson. In 1844, published an edition of Phillips's Mineralogy.

ANDREWS, EBENEZER BALDWIN. Theologian and geologist.

Born in Danbury, Conn., April 29, 1821; died in Lancaster, Ohio, August 14, 1880. Graduated from Marietta College in 1842. In 1851–1869, professor of geology in Marietta College, and then became assistant geologist to the Ohio State survey. Author of Text-book on Elementary Geology, Cincinnati, 1878.

ANTISELL, THOMAS, Physician and chemist.

Born in Dublin, Ireland, January 16, 1817; died in Washington, D. C., June 14, 1893. By profession a chemist and surgeon. Came to America in 1848 and practiced medicine in New York for six years, at same time lecturing in colleges in Woodstock, Vt., Pittsfield, Mass., and Berkshire Medical Institute. In 1854–1856, served as geologist on Pacific Railroad Survey under Lieut. J. G. Parke. In 1861–1865, surgeon in Union Army. In 1866–1870, chief chemist in Department of Agriculture. In 1871–1877, in Japan in service of Imperial Government as chemist and technologist.

Biogr. Wm. H. Seamans, Philos. Soc. of Washn., Bull. XIII, pp. 367–434.
Yearbook of Agr. Dept., 1899, p. 238.

ASHBURNER, CHARLES ALBERT. Mining engineer.

Born in Philadelphia, Pa., February 9, 1854; died in Pittsburg, Pa., December 24, 1889. Economic geologist with especial reference to petroleum, gas, coal, and iron. Trained as a civil engineer, but soon abandoned the calling for that of geologist. Geologist to second geological survey of Pennsylvania, 1873–1886.

Biogr. Amer. Geologist, VI, August, 1890, pp. 69–78.

BARNES, DANIEL HENRY. Baptist clergyman and educator.

Born in Canaan, Columbia County, N. Y., April 25, 1785; killed in runaway accident in Troy, N. Y., October 27, 1828. Graduated in theology from Union College in 1809 and in 1816, became principal of the classical department of that institution. In 1819, made professor of languages in the Baptist Theological Seminary, New York City. Rendered valuable service on original edition of Webster's Dictionary. Published but one purely geological paper—a geological section of the Canaan Mountains.

Biogr. Am. Jour. Sci., XV, 1829, p. 401.

BARRIS, WILLIS HERVEY. Clergyman.

Born in Beaver County, Pa., July 9, 1821; died in Davenport, Iowa, June 10, 1901. Clergyman and teacher, interested in the sciences, particularly in geology. One of the founders of the Davenport Academy of Sciences. Published three brief papers on the local geology of Davenport.

Biogr. C. A. White. Annals of Iowa, October, 1901, p. 219.

BECK, LEWIS CALEB. Chemist.

Born in Schenectady, N. Y., October 4, 1798; died in Albany, N. Y., April 20, 1853. At time of death held the professorships of chemistry and natural history at Rutgers College, New Jersey, and of chemistry in Albany Medical College.

Am. Jour. Sc., XVI, 1853, pp. 149–150.

BIGSBY, JOHN J. Physician.

A British medical officer. Wrote principally on Canadian geology.

BILLINGS, ELKANAH. Paleontologist.

Born in Gloucester, Canada, May 5, 1820; died in Montreal, Canada, June 14, 1876. Educated as a lawyer. In 1852–1855, editor of the Citizen, at Renfrew, Canada. In 1856 established the Canadian Naturalist. From 1856 to time of his death paleontologist to the provincial government.

Biogr. Henry M. Ami. Amer. Geologist, XXVII, No. 5, 1901, pp. 265–281.

BINNEY, AMOS. Conchologist.

Born in Boston, Mass., October 18, 1803; died in Rome, Italy, February 18, 1847. Graduated from Brown University in 1821.

Blake, William Phipps. Geologist.

Born in New York, June 1, 1826. Graduated from Yale Scientific School in 1852. Geologist and mineralogist for U. S. Pacific Railroad Expedition in 1853. Became professor of mineralogy and geology, College of California, 1864; now director of School of Mines, University of Arizona, and Territorial geologist.

Booth, James Curtis. Chemist.

Born in Philadelphia, Pa., July 28, 1810; died in West Haverford, Pa., March 21, 1888. Professor of applied chemistry, Franklin Institute. In 1849 appointed superintendent of smelting and refining precious metals in United States Mint. Assistant on geological survey of Pennsylvania and State geologist of Delaware, 1839–1841.

Lamb's Biog. Dict. of United States.

Bradley, Frank Howe. Geologist.

Born in New Haven, Conn., September 20, 1838; died near Nacoochee, Ga., March 27, 1879. In 1867, assistant geologist, State survey of Illinois. In 1869–1875, professor of geology and mineralogy in the University of Tennessee. During summer of 1872, assistant geologist in the Hayden surveys. After 1875 engaged in private work. Killed by a cave-in in a gold mine.

Am. Jour. Sci., XVII, 1879, p. 415.

Bramby, R. S.

Born in Statesburg, S. C., August 4, 1804; died near Athens, Ga., October 6, 1871. Received a classical education and became first a lawyer, then a newspaper editor. From 1834 to 1849, professor of chemistry, mineralogy, and geology in the University of Alabama. In the latter year elected to a similar position in South Carolina College in Columbia, S. C., where he remained until 1856.

Branner, John Casper. Geologist.

Born in Newmarket, Tenn., July 4, 1850. Graduated from Cornell, 1874. Geologist on Imperial Geological Commission, Brazil, 1875–1877; topographical geologist, geological survey of Pennsylvania, 1883–1885; professor of geology, University of Indiana, 1885–1892; State geologist of Arkansas, 1887–1892. Professor of geology, Leland Stanford Junior University, since 1892.

Brewer, William Henry. Chemist and geologist.

Born in Poughkeepsie, N. Y., September 14, 1828. Graduated from Yale in 1852; studied at Heidelberg, Munich, and Paris. Professor of chemistry and geology, Washington College, Pennsylvania, 1858–1860; first assistant on geological survey of California, 1860–1864; professor of chemistry, University of California, 1863–64. Professor of agriculture at Yale since 1864.

Briggs, Caleb.

Born in North Rochester, Mass., May 24, 1812; died in North Rochester, Mass., September 28, 1884. Assistant on geological survey of Ohio under Mather, 1837, and on geological survey of Virginia under Rogers in 1839. Worked principally in the coal and iron formations.

Biogr. Chas. Whittlesey. Mag. of Western History, II, 1885.

Broadhead, Garland Carr. Geologist.

Born in Albemarle County, Va., October 30, 1827. Civil engineer, Pacific Railroad of Missouri, 1852–1857; assistant geologist of Missouri, 1857–1861 and 1871–1873; State geologist of Missouri, 1873–1875; assistant geologist of Illinois, 1868; professor of geology, University of Missouri, 1887–1897.

Brooks, Thomas Benton. Geologist.

Born in Monroe, N. Y., June 15, 1836; died in Newburgh, N. Y., November 22, 1900. Began life as a land surveyor. In 1865, engaged on general survey of New Jersey. In 1866–1869, vice-president and general manager of Iron Cliff mine in the Marquette district of Michigan. In 1869–1873, connected with State survey of Michigan.

Biogr. Bailey Willis. Science, Mar. 22, 1901.

BRUCE, ARCHIBALD. Physician and mineralogist.

Born in New York City in February, 1777; died in New York, February 22, 1818. During a two years' tour of Europe he collected a valuable mineralogical cabinet, and returned to the United States in 1803, to enter on the practice of medicine. Assisted in organization of College of Physicians and Surgeons of State of New York. Established Journal of American Mineralogy. Professor of materia medica and mineralogy in College of Physicians of New York and Rutger's College, New Jersey.

Biogr. Am. Jour. Sci., I, 1819, pp. 299–304.

BUCKLEY, SAMUEL BOTSFORD. Botanist.

Born near Penn Yan, in Yates County, New York, May 9, 1809; died in Austin, Tex., February 18, 1884. Graduate of Wesleyan University, Middletown, Conn., 1836. Taught botany in Illinois, Alabama, and other Southern States. Discovered zeuglodon skeleton in Clarke County, Ala., in 1841. In 1866–67, State geologist of Texas.

Bull. Torrey Botanical Club, XI.

CHAMBERLIN, THOMAS CROWDER. Geologist.

Born in Mattoon, Ill., September 25, 1843. Graduate of Beloit, 1866. Professor of natural science, State normal school, Whitewater, Wis., 1869–1873; professor of geology, Beloit, 1882–1887; president of University of Wisconsin, 1887–1892. Assistant State geologist Wisconsin, 1873–1876; chief geologist Wisconsin, 1876; United States geologist in charge of glacial division since 1882; geologist of Peary Relief Expedition, 1894. Since 1892 head professor of geology, University of Chicago.

CHANCE, HENRY MARTYN. Mining engineer and geologist.

Born in Philadelphia, January 18, 1856. Graduated from University of Pennsylvania, 1874. Assistant geologist, Pennsylvania geological survey, 1874–1884.

CHURCH, JOHN ADAMS. Metallurgist and mining engineer.

Born in Rochester, N. Y., April 5, 1843. Graduated from Columbia in 1867. Acting professor of mineralogy and metallurgy, Columbia School of Mines; editor Engineering and Mining Journal, 1872–1874; for some time connected with U. S. Geological Survey; professor mining and metallurgy, Ohio State University, 1878–1881.

CLAYPOLE, EDWARD WALLER. Geologist.

Born in Ross, Hereford, England, June 1, 1835; died in Long Beach, Cal., August 17, 1901. Came to United States in 1872 and became professor of natural science at Antioch College, Yellow Springs, Ohio, in 1873. In 1881–1883, connected with second geological survey of Pennsylvania. In 1883, appointed professor of natural science in Buchtel College, Akron, Ohio. In 1898 to time of his death, professor of geology and biology at Throop Polytechnic Institute, Pasadena, Cal.

Biogr. Theo. B. Comstock and Geo. M. Richardson. Amer. Geol., XXIX, 1902, No. 1, pp. 1–47.
T. B. Comstock. Bull. Geol. Soc. of America, XIII, Feb., 1903, pp. 487–97.

CLEAVELAND, PARKER. Chemist and mineralogist.

Born in Essex, Mass., January 15, 1780; died in Brunswick, Me., October 16, 1858. Graduated at Harvard in 1799. In 1805, appointed professor of mathematics, natural philosophy, chemistry, and mineralogy in Bowdoin College, and continued to teach these branches (with exception of mathematics) until time of his death. Is best remembered as a teacher and mineralogist.

Biogr. Am. Jour. Sci., XXVI, 1858, pp. 448–9.

COLLETT, JOHN. Geologist.

Born in Eugene, Ind., January 10, 1828; died in Indianapolis, Ind., March 15, 1899. Graduated from Wabash College, Crawfordsville, Ind., in 1847. From 1869 to 1879 assistant under E. T. Cox in State survey of Indiana, and in last-named year made State geologist and statistician. 1880 appointed geologist in chief for a term of four years. At the end of his term of service he retired to private life.

Conkling, Alfred Ronald.

Born in New York, September 28, 1850. Graduated from Yale in 1870. For a short time connected with U. S. Geological Survey under Hayden.

Conrad, Timothy Abbott. Conchologist and paleontologist.

Born near Trenton, N. J., June 21, 1803; died in Trenton, N. J., August 9, 1877. By profession a printer. Geologist and paleontologist of New York State, 1827–1842. Prepared official reports on the fossils collected by the Wilkes Exploring Expedition, the expedition of Lieutenant Lynch to the Dead Sea, and the Mexican Boundary Survey. He also published an important work on the fossil shells of the Tertiary formation of North America.

Biogr. Wm. H. Dall. Proc. Biolog. Soc. of Washington, IV, 1886–88, pp. 112–114.

Cook, George Hammell. Geologist.

Born in Hanover, N. J., January 5, 1818; died in New Brunswick, N. J., September 22, 1889. In 1839–1842, tutor or adjunct professor and 1842–1846, senior professor at the Rensselaer Polytechnic Institute. In 1848–1851, connected with Albany Academy at Albany, N. Y. In 1853, professor of chemistry and natural science at Rutgers College, New Brunswick, N. J. In 1854–1856, assistant geologist of State of New Jersey. In 1864, made State geologist, a position which he continued to fill till time of his death.

Biogr. James Neilson. Address before faculty of Rutgers College, 1890.

Cooper, Thomas. Educator.

Born in London, England, October 22, 1759; died in Columbia, S. C., May 11, 1840. Came to America in 1795 and served for brief periods as professor of chemistry and allied sciences and law in Dickinson College, University of Pennsylvania, University of Virginia, and South Carolina College, becoming president of last named in 1821 and serving until 1833.

Biogr. History of Higher Education in South Carolina by Colyer Meriweather. Bureau of Education, Washn., 1889.

Cope, Edward Drinker. Paleontologist.

Born in Philadelphia, Pa., July 28, 1840; died in Philadelphia, April 12, 1897. Vertebrate paleontologist. Professor of natural science at Haverford College, Pa., 1864–1867; connected with the U. S. Geological Surveys under Lieut. G. M. Wheeler, 1874, and Dr. F. V. Hayden. Curator of Academy of Natural Sciences of Philadelphia, 1865–1873. Professor of geology, University of Pennsylvania, 1889. For many years editor of the American Naturalist.

Biogr. P. Frazer. Amer. Geol., XXVI, Aug., 1900.

Cornelius, Elias. Clergyman.

Born in Somers, N. Y., July 31, 1794; died in Hartford, Conn., February 12, 1832. A clergyman who, in company with many others of his time, was interested in the sciences. Wrote a little, but did no active work.

Biogr. Bela Hubbard. Nat. Cyclo. Am. Biogr, 1833.

Cotting, John Ruggles. Clergyman.

Born in Acton, Mass., 1784; died in Milledgeville, Ga., October 18, 1868. A clergyman interested in science. Removed to Augusta, Ga., in 1835, and was engaged by private parties to make agricultural survey of Burke and Richmond counties. The work was completed in 1836, and map and drawings deposited in the Medical College at Augusta. Report published in 1836. State geologist of Georgia for two years.

Biogr. Am. Min. Jour., XLV, 1868. p. 141.

Couthouy, Joseph Pitty. Conchologist.

Born in Boston, Mass., January 6, 1808, of French extraction; shot on U. S. S. *Chillicothe*, off Grand Ecore, La., April 3, 1864, and died following day. In early life shipped as sailor on his father's vessel. In 1836, became member of Boston Society of Natural History; was conchologist to Wilkes Exploring Expedition for two years. Commanded United States vessels from outbreak of rebellion until he lost his life.

Biogr. Wm. H. Dall. Some Amer. Conchologists. Proc. Biolog. Soc. of Washn., IV, 1886-88, pp. 108-111.

Cox, Edward Travers. Geologist.

Born in Culpeper County, Va., April 21, 1821. Studied geology and chemistry under D. D. Owen and served as assistant on surveys of Kentucky and Arkansas. In 1868-1880, State geologist of Indiana.

Cozzens, Issachar.

Born in Newport, R. I., December 15, 1780, died in Guttenberg, N. J., April 17, 1865. Cozzens's claim to recognition as a geologist, so far as his publications are concerned, is based upon his geological history of Manhattan or New York Island, dated 1843.

Biogr. Genl. A. W. Vogdes. Amer. Geolog., XXIV, No. 6, 1899, pp. 327-8.

Dale, Thomas Nelson. Geologist.

Born in New York City, November 25, 1845. Professor of geology, zoology, and botany, Drury College, Missouri, 1877; professor of geology, Vassar College, 1878; connected with U. S. Geological Survey since 1885—as field assistant, 1885-1889; assistant geologist, 1890-91; geologist, 1892 to date. Instructor in Williams College—in geology, 1893; botany, 1897; resigned, 1901.

Dall, William Healey. Naturalist.

Born in Boston, Mass., August 21, 1845. Studied natural sciences under Louis Agassiz. Paleontologist on U. S. Geological Survey, 1884-1898. Since 1880, attached to U. S. National Museum; since 1893, also professor invertebrate paleontology, Wagner Institute of Sciences, Philadelphia.

Dana, Edward Salisbury. Mineralogist.

Born in New Haven, Conn., November 16, 1849. Graduated from Yale University in 1870; also studied in Heidelberg and Vienna. Member of Yale faculty since 1874. Editor American Journal of Science. Author of Text-Book and System of Mineralogy.

Dana, James Dwight. Geologist.

Born in Utica, N. Y., February 12, 1813; died in New Haven, Conn., April 14, 1895. Entered Yale in 1830, but withdrew in August, 1833, to become instructor in mathematics in the Navy. In 1836, reentered Yale, remaining two years, serving as assistant to Professor Silliman. In 1838-1842, geologist and mineralogist to the Wilkes Exploring Expedition. In 1846, became editor of American Journal of Science. In 1850, appointed professor of natural history in Yale College, the title in 1864 being changed to professor of geology and mineralogy. Retained this chair until 1890, when he retired from active university work. "The foremost geologist of America and one of the foremost of the world."

Biogr. E. S. Dana. Am. Jour. Sci., XLIX, 1895, pp. 1-28.
C. E. Beecher, Am. Geol., XVII, 1896, pp. 1-16.
Joseph Le Conte. Bull. Geol. Soc. Amer., VII, 1895, pp. 461-479.
D. C. Gilman. The Life of James Dwight Dana, 1899.

Dana, Samuel Luther. Chemist.

Born in Amherst, N. H., July 11, 1795; died in Lowell, Mass., March 11, 1868. Graduated in medicine in 1818 and practiced until 1826. Chemist to the Newton Chemical Company, from about 1826-1834. Consulting chemist of Merrimac Manufacturing Company, at Lowell, Mass., 1834-1868. With his brother J. F. Dana, published a work on the mineralogy and geology of Boston and vicinity.

Biogr. Pop. Sci. Monthly, pp. 692-697.
Am. Jour. Sci., XLV, 1868, p. 425.

DAWSON, GEORGE MERCER. Geologist.

Born in Pictou, Nova Scotia, August 1, 1849; died in Ottawa, Canada, March 2, 1901. Graduated at the London School of Mines in 1872, and became geologist and botanist on North American Boundary Surveys, 1873. Connected with Geological Survey of Canada from 1875 to time of his death, succeeding Selwyn as director in 1895.

Biogr. Frank D. Adams. Bull. Geol. Soc. of America, XIII, Feb., 1903, pp. 497–509.

DAWSON, JOHN WILLIAM. Stratigraphical geologist and paleobotanist.

Born in Pictou, Nova Scotia, October 13, 1820; died in Montreal, Canada, November 19, 1899. Superintendent of education in Nova Scotia, 1850. Principal of McGill University, 1855–1893. The author of many works bearing upon science and religion; his most important books being Acadian Geology, the first edition of which appeared in 1855; the Geological History of Plants; Air Breathers of the Coal Period; and the Dawn of Life. One of the most eminent advocates of the theory of the organic origin of the *Eozoon canadense.*

Biogr. Bull. Geol. Soc. Amer., XI, 1899, pp. 550–580.
H. M. Ami. Amer. Geol., XXVI, 1900, pp. 1–57.
Eng. & Min. Jour., LXVIII, No. 23, Dec. 2, 1899, p. 664.
Canadian Rec. of Sci., VIII, 1900, pp. 137–149.

DEANE, JAMES. Physician.

Born in Coleraine, Mass., February 24, 1801; died in Greenfield, Mass., June 8, 1858. Physician by profession, his claim to geological recognition being founded upon his work on fossil footprints in the sandstones of the Connecticut Valley, to the study of which, contemporaneously with Hitchcock, he devoted much attention.

DEWEY, CHESTER. Naturalist.

Born in Sheffield, Mass., October 25, 1784; died in Rochester, N. Y., December 5, 1867. Tutor in Williams College, 1808–1810. In 1810–1817, professor of mathematics and natural philosophy, also professor and lecturer on chemistry and botany in medical colleges of Pittsfield, Mass., and Woodstock, Vt., for many years. In 1836–1850, principal of the Collegiate Institute of Rochester, N. Y. In 1850–1860, professor of chemistry and natural philosophy, University of Rochester.

DUCATEL, JULIUS TIMOLEON. Chemist.

Born in Baltimore, Md., June 6, 1796; died there April 23, 1849. Professor of natural philosophy in Mechanic's Institute of Baltimore, and of chemistry and geology in faculty of arts and sciences in the University of Maryland. In 1830 succeeded Doctor Butts in the chair of chemistry in the medical department of the university. In 1835, in conjunction with J. H. Alexander, made a preliminary reconnaissance of Maryland; was appointed professor of chemistry, mineralogy, and geology in St. John's College, Annapolis, but in 1838 or 1839 resigned both appointments to devote himself to the survey work.

Obituary. Am. Jour. Sci., VIII, 1849, pp. 146–149.

DUTTON, CLARENCE EDWARD. Major in United States Army and geologist.

Born in Wallingford, Conn., May 15, 1841. Graduated from Yale in 1860. Entered United States Army in 1862, and after civil war devoted leisure to study of geology. In 1875–1891, detailed for duty with U. S. Geological Survey.

DWIGHT, WILLIAM BUCK. Geologist.

Born in Constantinople, Turkey, May 22, 1833. Graduated from Yale University, 1857. In 1865–1867, engaged in mining explorations in Virginia and Missouri. In 1867–1870, taught at West Point. In 1870–1878, professor of natural sciences at State Normal School of Connecticut; since 1878, professor of natural history, Vassar College.

EATON, AMOS. Geologist and educator.

Born in Chatham, N. Y., May 17, 1776; died in Troy, N. Y., May 6, 1842. Graduated from Williams College, 1799, and subsequently studied and practiced law. In

1815, studied mineralogy and geology with Professor Silliman. Returned to Williams College and gave course of lectures on botany, geology, and mineralogy to volunteer students. In 1820, appointed professor of natural history in Medical College at Castleton, Vt. In 1820–21, engaged on geological and agricultural survey of Albany and Rensselaer counties, N. Y. In 1823–24, on survey of district adjoining the Erie Canal. In 1824, made senior professor of school of sciences, Rensselaer Polytechnic Institute, where he remained till his death.

Biogr. Pop. Sci. Monthly, XXXVIII, November, 1890, pp. 113–118.

EMMONS, EBENEZER. Geologist.

Born in Middlefield, Mass., May 16, 1799; died in Brunswick County, N. C., October 1, 1863. Graduated at Williams College, Massachusetts, in 1820, and for fifteen years practiced medicine and surgery in Berkshire. In 1838–1852, professor of chemistry at the Albany Medical School. In 1828, lecturer on chemistry in Williams College. In 1833, appointed professor of natural history to succeed C. Dewey. In 1836, appointed geologist of Second District New York State geological survey; from 1851 to 1863 State geologist of North Carolina. Is best remembered as the originator and defender of the Taconic system in North America.

Biogr. Jules Marcou. Amer. Geol., Jan., 1891, pp. 1–23.
Am. Jour. Sci., XXXVII, May, 1864, p. 151.
Pop. Sci. Monthly, Jan., 1896.

EMMONS, SAMUEL FRANKLIN. Geologist.

Born in Boston, Mass., March 29, 1841. Graduated from Harvard in 1861. Studied in Paris and at Freiberg Mining School, Saxony, 1862–1865. Geologist Fourtieth Parallel Survey, 1867–1877. On U. S. Geological Survey, 1879 to date.

ENDLICH, FREDERIC MILLER. Mining engineer.

Born in Reading, Pa., June 14, 1851; died in Tucson, Ariz., July 17, 1899. In 1872–1880, mineralogist and chemist at Smithsonian Institution. In 1873–1879, assistant on U. S. Geological and Geographical Surveys under F. V. Hayden. From 1880 to time of his death engaged as mining engineer in various parts of the West.

ENGELMANN, GEORGE. Naturalist.

Born in Frankfort-on-Main, Germany, February 2, 1809; died in St. Louis, Mo., February 4, 1884. Graduated at Wurzburg University in 1831. Came to America in 1832 and prepared specimens of plants for German museums. In 1835, began the practice of medicine in St. Louis. His records of meteorological observations in the Mississippi Valley are a most valuable source of information on climatology during fifty years. Voluminous writer on botany and other branches of natural history. First president of Academy of Science of St. Louis.

Biogr. Enno Sander. Trans. Acad. of Sci. St. Louis, IV, 1878-86, prelim. pages 1–13.
C. A. White. Biogr. Mems. Natl. Acad. Sci., IV., 1902, pp. 1–21.

EVANS, JOHN. Physician and geologist.

Born in Portsmouth, N. H., February 14, 1812; died in Washington, D. C., April 13, 1861. In 1847, was assistant to D. D. Owen in the Chippewa district. In 1851, appointed to institute geological researches in Oregon and Washington. Went to Central America with Chiriqui Exploring Expedition, 1860.

Biogr. Am. Jour. Sci., XXXII, Nov., 1861, p. 311.

FEATHERSTONHAUGH, GEORGE WILLIAM.

Born in London, 1780; died in Havre, France, September 28, 1866. Came to United States and in 1834, made examination of the region between the Missouri and Red Rivers. In 1835, made geological reconnaissance from Washington to St. Peters River. Appointed by Great Britain one of commission of two to settle boundary dispute between United States and Canada. British Consul at Havre, assisting in escape of Louis Phillipe in 1848.

J. D. Featherstonhaugh. Am. Geol., April, 1889.

FOSTER, JOHN WELLS.

Born in Petersham, Mass., March 4, 1815; died in Hyde Park, Chicago, Ill., June 20, 1873. Received collegiate education at Wesleyan University, Middletown, Conn., after which he studied law and settled at Zanesville, Ohio. Was assistant to Jackson, and subsequently worked with Whitney on survey of copper lands of Lake Superior. Wrote work on Prehistoric Races of the United States and on The Mississippi Valley, Its Physical Geography, etc., in 1869.

Biogr. Pop. Sci. Monthly, III, August, 1873, p. 508.

FRAZER, PERSIFOR. Geologist and chemist.

Born in Philadelphia, Pa., July 24, 1844. Graduated from University of Pennsylvania, 1862; studied in Royal School of Mines, Freiberg, Saxony, 1866–1869. Mineralogist and metallurgist on U. S. Survey under Hayden, 1869–70. Professor of chemistry, University of Pennsylvania, 1870–1874; assistant on second geological survey of Pennsylvania, 1874–1882.

GABB, WILLIAM MORE. Paleontologist.

Born in Philadelphia, Pa., January 20, 1839; died there, May 30, 1878. In 1862, paleontologist on geological survey of California under Whitney. In 1868, undertook survey in Santo Domingo for private company, and in 1873, published a memoir of topography and geology of that island. In 1873, went to Costa Rica and engaged in a geological and topographical survey.

Biogr. Amer. Jour. Sci., XVI, 1878, p. 164.

GENTH, FREDERICK AUGUSTUS. Mineralogist and chemist.

Born in Waechtersbach, in Hesse, May 17, 1820; died in Philadelphia, Pa., February 2, 1893. Took degree of Ph. D. at University of Marburg in 1845; chemical assistant to Bunsen for three years. In 1848, came to America and settled in Philadelphia. In 1872–1888, professor of chemistry in University of Pennsylvania. Best known by his studies of corundum, copper products, and ammónia-cobalt bases.

Biogr. Geo. F. Barker. Natl. Acad. Sci., Biogr. Mems., IV, 1902, pp. 203–231.

GESNER, ABRAHAM. Physician, geologist, and chemist.

Born in Cornwallis, Nova Scotia, May 2, 1797; died in Halifax, Nova Scotia, April 19, 1864. In 1838, appointed provincial geologist of New Brunswick. Aside from his geological work, he achieved distinction as inventor of method for manufacture of illuminating oil from coal and other bituminous substances.

Biogr. G. W. Gesner. Bull. XIV, Natl. Hist. Soc. of New Brunswick, 1896.

GIBBS, GEORGE.

Born in Newport, R. I., January 7, 1776; died in Sunswick, near Halletts Cove (now New York City), L. I., August 6, 1833. First vice-president of American Geological Society, founded in 1819; owner of one of the finest mineralogical cabinets of the time.

GIBBS, GEORGE. Lawyer and geologist. Son of Col. George Gibbs.

Born in Sunswick, near Halletts Cove (now New York City), L. I., July 17, 1815; died in New Haven, Conn., April 9, 1873. Graduated from Harvard University and entered upon the practice of law. In 1848, accompanied military expedition to the far West, and settled at Columbia, Oreg. Geologist to survey of railroad route to Pacific; in 1857, appointed on northwest boundary survey, submitting report on geology and natural history of the country. Secretary of Hudson Bay Claims Commission; for some time before his death connected with Smithsonian Institution upon ethnological and philological work.

Biogr. J. A. Stevens. Ann. Rept. Smith. Inst. for 1873, pp. 219–225.

GIBSON, JOHN BANNISTER. Jurist.

Born in Carlisle, Pa., November 8, 1780; died in Philadelphia, Pa., May 3, 1853. Graduated from Dickinson College in 1798 and admitted to the bar in 1803. Wrote on the trap rocks of the Conewago Hills.

GILBERT, GROVE KARL. Geologist.

Born in Rochester, N. Y., May 6, 1843. Graduated from University of Rochester, 1862. Assistant in Ward Museum, Rochester, 1863–1868; geologist on Ohio survey, 1868–1870; on Wheeler survey, 1871–1874; Powell survey, 1875–1879; geologist on U. S. Geological Survey since 1879.

GREEN, JACOB. Conchologist and paleontologist.

Born in Philadelphia, Pa., July 26, 1790; died there February 1, 1841. Graduated from University of Pennsylvania in 1806; professor of chemistry and natural history in Princeton, 1818–1822; professor of chemistry in Jefferson Medical College, Philadelphia, until his death. Wrote on chemistry, paleontology, and botany.

Biogr. Wm. H. Dall. Some Amer. Conchologists, Proc. Biolog. Soc. Washn., IV., 1886–88, p. 104.

GRINNELL, GEORGE BIRD.

Born in Brooklyn, N. Y., September 20, 1849. Graduated from Yale in 1870. Assistant in osteology in Peabody Museum, Yale, 1874–1880.

HAGER, ALBERT DAVID. Geologist.

Born in Chester, Vt., November 1, 1817; died in Chicago, Ill., July 29, 1888. In 1855–1857, assistant State naturalist of Vermont. In 1857–1861, assistant State geologist. In 1862–1870, State geologist and curator of the State cabinet of natural history. In 1870–1872, State geologist of Missouri. In 1877–1888, librarian Chicago Historical Society.

HAGUE, ARNOLD. Geologist.

Born in Boston, Mass., December 3, 1840. Graduated from Yale, 1863; studied at universities of Göttingen and Heidelberg and Freiberg School of Mines, 1863–1867. Geologist on Fortieth Parallel Survey, 1867–1877. Government geologist of Guatemala, 1877–78; engaged in examining mines in northern China, 1878–79; since 1879 a member of U. S. Geological Survey.

HAGUE, JAMES DUNCAN. Mining engineer.

Born in Boston, Mass., February 26, 1836. Educated at Harvard and Göttingen, Germany, and Royal School of Mines, Freiberg, Saxony. Exploring in South Seas, 1859–1861; manager of copper mines at Lake Superior, 1863–1866; geologist on U. S. Geological Survey fortieth parallel, 1867–1870.

HALDEMAN, SAMUEL STEHMAN. Naturalist.

Born in Locust Grove, Pa., August 12, 1812; died in Chickies, Pa., September 10, 1880. Assistant to H. D. Rogers in geological survey of New Jersey in 1836; astronomer on survey of Pennsylvania, 1837–38. In 1851–1855, professor of natural history in University of Pennsylvania; in 1855, became professor of natural history in Delaware College, Dover, Del.; in 1869–1880, professor of comparative philology in University of Pennsylvania. A very versatile man and author of some thirty works on philology and one hundred and twenty on various natural science subjects.

Biogr. J. P. Lesley. Nat. Acad. Sci., Biog. Mems., II, 1886.

Wm. H. Dall. Some Amer. Conchologists, Proc. Biolog. Soc. Washn., IV, 1886–88, pp. 112–113.

HALL, JAMES. Paleontologist.

Born in Hingham, Mass., September 12, 1811; died in Echo Hill, Bethlehem, N. H., August 7, 1898. Studied under Eaton at Rensselaer Institute, Troy, where he was subsequently assistant professor. Connected with geological survey of New York—first as assistant to Emmons; took charge of fourth district; after 1843, had charge of entire survey, in which he continued until his death, sometimes carrying on work at his own expense. Besides the New York reports he contributed to Foster and Whitney's Report on the Lake Superior Region, the Mexican Boundary Report, etc. At one time State geologist of Iowa, and afterwards of Wisconsin. In conjunction with R. P. Whitfield he published important memoirs on paleontology of Ohio, Kentucky, and the Fortieth Parallel.

Biogr. John J. Stevenson. Bull. Geol. Soc. of America, X, 1898, pp. 425–451.

Geol. Mag., Dec. IV, V, 1898, p. 431.

HALL, JAMES. Clergyman.

Born in Carlisle, Pa., August 22, 1744; died in Bethany, N. C., July 25, 1826. Graduated from Princeton University in 1774. Maintained at his home in North Carolina an "academy of sciences," in which he was the only teacher.

HARLAN, RICHARD. Physician and paleontologist.

Born in Philadelphia, Pa., September 19, 1796; died in New Orleans, La., September 30, 1843.

HARPER, LEWIS (Ludwig Hafner).

Of Hamburg, Germany. In 1855–1857, professor of geology and agriculture and State geologist of Mississippi.

HARTT, CHARLES FREDERICK. Geologist.

Born in Fredericton, New Brunswick, August 23, 1840; died in Rio Janeiro, Brazil, March 18, 1878. In 1864, connected with geological survey of New Brunswick. In 1865–1866, geologist on the Thayer Expedition to Brazil. In 1868, appointed professor of natural history in Vassar College, but resigned shortly to accept chair of geology in Cornell University, which he held until time of his death. In 1875, appointed chief of the geological commission of Brazil.

Biogr. G. F. Matthew. Bull. Nat. Hist. Soc. of N. B., IX, 1890, pp. 1–24.

HAWN, FREDERICK. Civil engineer.

Born in Herkimer County, N. Y., January 5, 1810; died in Leavenworth, Kans., January 31, 1898. About 1851 appointed by Swallow assistant on Missouri geological survey, and gave particular attention to study of the coal regions. Is best known in connection with the discovery of the Permian formation in Kansas.

Biogr. G. C. Broadhead. Am. Geol., XXI, 1898, pp. 267–69.

HAY, ROBERT. Geologist.

Born of Scottish ancestors, May, 1835, in Lancashire, England; died in Junction City, Kans., December 14, 1895. Came to America in 1871, and for ten years taught in the public schools. In 1881 appointed State geologist of Kansas. In 1890 geologist in charge of the artesian investigation of the Great Plains under Department of Agriculture. During last five years of his life connected with U. S. Geological Survey in special work on underground waters of Kansas. His papers were about thirty, principally upon geology.

Biogr. Robt. T. Hill. Bull. Geol. Soc. Amer., VIII, 1896, pp. 370–74.

HAYDEN, FERDINAND VANDIVEER. Geologist.

Born in Westfield, Mass., September 7, 1829; died in Philadelphia, Pa., December 22, 1887. Graduated from Oberlin College in 1850. Assistant to James Hall in 1853; engaged in independent geological work in the West, 1854–1856. Geologist to the Warren Expedition to the Yellowstone region in 1856 and to the Black Hills in 1857. In 1858, with Meek, engaged in explorations in Kansas. In 1859, appointed surgeon and naturalist to exploring party under Capt. W. F. Raynolds about the headwaters of the Missouri. In 1865–1872, professor of geology and mineralogy in University of Pennsylvania. In 1869, appointed United States geologist in charge of survey of Nebraska, and in 1868 to similar position in Wyoming. In 1869–1879, Director U. S. Geological and Geographical Surveys, and from 1880–1886, geologist on United States geological surveys under J. W. Powell.

Biogr. C. A. White. Mem. Nat. Acad. Sci., November, 1894.

HAYDEN, HORACE H.

Born in Windsor, Conn., October 13, 1768; died in Baltimore, Md., January 26, 1844. Trained for profession of architect, and subsequently became practicing dentist. His chief claims to geological recognition lies in his authorship of geological essays published in 1820 and two papers on local geology.

Biogr. Amer. Journal Dental Sciences, IV, No. 4, 1844.

HILDRETH, SAMUEL PRESCOTT. Physician.

Born in Methuen, Mass., September 30, 1783; died in Marietta, Ohio, July 24, 1863. Settled in Ohio at Belpre in 1806, and in 1808 removed to Marietta, where he began the first meteorological register in the State, keeping it up for fifty years. One of a commission of three in 1836 to report on geological survey of Ohio. Served as assistant geologist for a time under Mather. His work is largely of an historical nature.

Biogr. Chas. Whittlesey, Mag. of Western History, 1881.
Amer. Journ. Sci., XXXVI, 1863, p. 312.

HILGARD, EUGENE WALDEMAR. Chemist and geologist.

Born in Zweibrucken, Rhenish Bavaria, January 5, 1833. Came to America in 1835. Educated in Germany, returning to America in 1855. In 1855–1856, assistant to B. L. C. Wailes on State geological survey of Mississippi. In 1856–1857, chemist of the Smithsonian Institution and lecturer on chemistry in National Medical College. In 1858–1860, State geologist of Mississippi. In 1865–1873, professor of chemistry at University of Mississippi. In 1873–1875, professor of geology and natural history, University of Michigan. Since 1875, professor of agricultural chemistry in University of California.

Biogr. Nat. Cyclo. Amer. Biog., X, p. 308.

HIND, HENRY YOULE. Chemist and geologist.

Born in Nottingham, England, June, 1823. Educated at Leipzig and Cambridge. Came to America in 1846 and the following year settled in Canada. In 1851, became professor of chemistry and geology in Trinity College, Toronto. In 1857, geologist to Red River Exploring Expedition. In 1858, in charge of exploration of country between Red River and Saskatchewan. In 1861, made explorations in Labrador, and in 1864, appointed director of geological survey of New Brunswick. Professor of chemistry and natural history in Kings College, Nova Scotia.

HITCHCOCK, CHARLES HENRY. Geologist.

Born in Amherst, Mass., August 23, 1836. Graduated from Amherst College, 1856. Assistant State geologist of Vermont, 1857–1861; State geologist of Maine, 1861–1862; State geologist of New Hampshire, 1868–1878. In 1866, elected professor of geology in Lafayette College. Since 1868, professor of geology in Dartmouth College.

HITCHCOCK, EDWARD. Geologist, clergyman, and educator.

Born in Deerfield, Mass., May 23, 1793; died in Amherst, Mass., February 27, 1864. Educated as a clergyman and settled over a Congregational Church at Conway, Mass., from 1821–1825. In 1825–1845, professor of chemistry and natural history at Amherst College; in 1845–1855, president of Amherst College; in 1855–1864, professor of geology in Amherst College. In 1830–1833 and 1841–1844, State geologist of Massachusetts; in 1857–1860, State geologist of Vermont. Is best remembered for his work on the drift and the fossil footprints of the sandstones of the Connecticut Valley.

Biogr. C. H. Hitchcock. Am. Geol. XVI, 1895, pp. 133–149.
Pop. Sci. Monthly, XLVII, Sept., 1895, pp. 689–696.
Am. Jour. Sci., XXXVII, May, 1864, p. 302.
Biogr. Mems., Natl. Acad. Sci., I, 1877.

HODGE, JAMES THATCHER. Geologist.

Born in Plymouth, Mass., March 12, 1816; drowned in Lake Huron, October 20, 1871. Assistant on State geological survey of Maine under C. T. Jackson and on that of Pennsylvania under H. D. Rogers. Also served on geological surveys of New Hampshire and Ohio. Was engaged in exploration of mining regions of Lake Superior when drowned in wreck of steamer *R. G. Coburn*, on Lake Huron.

HOLMES, WILLIAM HENRY. Ethnologist.

Born in Harrison County, Ohio, December 1, 1846. Graduated from McNeely Normal College, 1870. Assistant on United States geological survey under Hayden, 1872–1880; geologist on United States survey under Powell, 1880–1889. Curator, U. S. National Museum, 1882–1893; archaeologist in explorations of U. S. Bureau Ethnology, 1889–1893; curator anthropology, Field Columbian Museum, 1894–1898; head curator of anthropology, U. S. National Museum, 1898–1904; Director, Bureau of American Ethnology, since 1905.

HOUGHTON, DOUGLASS. Explorer and geologist.

Born at Fredonia, N. Y., September 21, 1809; drowned near mouth of Eagle River, Lake Superior, October 13, 1845. Assistant to Eaton in natural sciences at the Rensselaer Polytechnic Institute, 1828. Admitted to practice of medicine in 1831. Surgeon and botanist to the Schoolcraft Exploring Expedition to the source of the Mississippi River; State geologist of Michigan, 1837–1845.

Biogr. Alvah Bradish. Mem. of Douglas Houghton, Detroit, 1889.
Alex. Winchell. Am. Geol., IV, Sept., 1889, pp. 129–139.
Am. Jour. Sci., V, 1848, pp. 217–227.

HOWELL, EDWIN EUGENE.

Born in Genesee County, N. Y., March 12, 1845. In 1872–1873, geologist with Wheeler survey west of one-hundredth meridian. In 1874, connected with the Powell survey of Rocky Mountain region.

HUBBARD, BELA.

Born in Hamilton, Madison County, N. Y., April 23, 1814; died in Detroit, Mich., June 13, 1896. Graduated from Hamilton College in 1834. Removed to Detroit, Mich., in 1835. Assistant State geologist of Michigan, 1838–1841.

Biogr. Mag. of Western History, IV, 1886.

HUBBARD, OLIVER PAYSON. Chemist.

Born in Pomfret, Conn., March 31, 1809; died in New York City, March 9, 1900. Assistant to B. Silliman in chemistry at Yale, 1831–1836. In 1836–1866, professor of chemistry, mineralogy, and geology in Darmouth College, Hanover, N. H. Lecturer on chemistry and pharmacy at same institution, 1866–1883.

Biogr. E. O. Hovey. Am. Geol., June, 1900, p. 360.

HUNT, THOMAS STERRY. Chemist.

Born in Norwich, Conn., September 5, 1826; died in New York City, February 12, 1892. In 1846–47, chemist to the geological survey of Vermont under C. B. Adams. In 1847–1872, chemist and mineralogist to the geological survey of Canada. In 1856–1862, lecturer on chemical geology in Laval University of Quebec; subsequently professor of chemistry and mineralogy in McGill University, Montreal. In 1872–1878, professor of geology in Massachusetts Institute of Technology.

Biogr. Persifor Frazer. Am. Geol., XI, 1893, pp. 1–13.
Canadian Record of Science, V, 1892–93, pp. 145–149.

HYATT, ALPHEUS. Biologist and paleontologist.

Born in Washington City, April 5, 1838; died in Cambridge, Mass., January 15, 1902. In 1867, curator in Essex Institute, Salem, Mass. In 1871, elected custodian of the Boston Society of Natural History, and in 1881, curator; professor zoology and paleontology in the Massachusetts Institute of Technology.

Biogr. R. S. Tarr. Pop. Sci. Monthly, Dec., 1885, pp. 261–267.
W. O. Crosby. Bull. Geol. Soc. Amer., XVI, 1903.

IRVING, ROLAND DUER. Geologist.

Born in New York, April 29, 1847; died in Madison, Wis., May 30, 1888. Began active life as superintendent of smelting works at Greenville, N. J. Assistant on State geological survey of Ohio. In 1870–1888, professor of geology, mineralogy, and metallurgy in University of Wisconsin. In 1873–1879, assistant geologist on geological survey of Wisconsin. In 1880–1888, connected with U. S. Geological Survey, working in Lake Superior region.

Biogr. T. C. Chamberlin. Am. Geol., III, 1889, pp. 1–6.

JACKSON, CHARLES THOMAS. Geologist and chemist.

Born in Plymouth, Mass., June 21, 1805; died in Somerville, Mass., August 28, 1880. Educated as physician, but early showed inclination toward geological work. In 1827–28, made geological explorations in Nova Scotia in company with Francis Alger. In 1837–1839, State geologist of Maine. In 1839–40, State geologist of Rhode Island. In 1839–1843, State geologist of New Hampshire. In 1847, appointed a United States geologist to investigate mineral land of Lake Superior region. Appointed one of the State geologists of New York, but declined.

Biogr. J. B. Woodworth. Am. Geol., XX, 1897, pp. 69–110.

JAMES, EDWIN. Physician.

Born in Weybridge, Vt., August 27, 1797; died near Burlington, Ill., October 28, 1861. In 1820, attached in capacity of botanist and geologist to Long's exploring expedition to sources of St. Peters River.

Biogr. Am. Jour. Sci., XXXIII, 1862, p. 428.

JAMES, URIAH PIERSON. Paleontologist.

Born in Goshen, Orange County, N. Y., December 30, 1811; died near Loveland, Ohio, February 25, 1889. Began life as printer and stereotyper and afterwards became publisher, in which profession he continued till the time of his death. His work, almost wholly paleontological, was done during spare moments.

Biogr. American Geologist, III, No. 5, 1889, pp. 281–285.

JOHNSON, WALTER ROGERS. Chemist.

Born in Leominster, Mass., June 21, 1794; died in Washington City, April 26, 1852. Prior to 1836 a teacher. In 1836–37, made a survey of coal and iron formations of Pennsylvania. In 1839–1843, professor of physics and chemistry, University of Pennsylvania. In 1843–44, Government expert on relative value of coals. In 1845, chemist at Smithsonian Institution. Founder of American Association of Naturalists and Geologists.

Biogr. Lamb's Biogr. Dict. of U. S.

KEATING, WILLIAM HYPOLITUS. Chemist.

Born in Wilmington, Del., August 11, 1799; died in London, England, May 17, 1840. In 1822–1828, professor of chemistry in University of Pennsylvania, and in 1823, accompanied Maj. S. H. Long in expedition to sources of the St. Peters River.

Biogr. Lamb's Biogr. Dict. of U. S.

KERR, WASHINGTON CARUTHERS. Geologist.

Born in the Alamance region of Guilford County, N. C., May 24, 1827; died in Asheville, N. C., August 9, 1885. At one time professor in Marshall University, Texas, resigning in 1852 to become a computer in the office of the Nautical Almanac. In 1857–1865, professor in Davidson College, North Carolina. In 1866–1882, State geologist of North Carolina. In 1882–83, connected with the U. S. Geological Survey.

Biogr. J. A. Holmes, Journ. Elisha Mitchell Scientific Soc., Part II, 1887, pp. 1–24.

KING, CLARENCE. Geologist.

Born in Newport, R. I., January 6, 1842; died in Phœnix, Ariz., December 24, 1901. Graduated at Sheffield Scientific School in 1862. In 1863, made a horseback journey across the continent, and for three years was volunteer assistant to Prof. J. D. Whitney on the geological survey of California. During 1865–66, made an exploration of the desert regions of southern California and Arizona as scientific aid to General McDowell. In 1866–67, organized the Geological Survey of the 40th Parallel and was appointed director. From 1879 until 1881, director of the newly organized U. S. Geological Survey.

Biogr. S. F. Emmons, Am. Jour. Sci., March, 1902, pp. 224–237.
S. F. Emmons, Eng. and Min. Jour., Dec. 28, 1901, p. 844; Jan. 4, 1902, pp. 1, 3.

KING, FRANKLIN HIRAM.

Born in Whitewater, Wis., June 8, 1848. Graduated from State Normal School, Whitewater, in 1872. On Wisconsin geological survey, 1873–1876; professor of natural sciences, River Falls State Normal School, 1878–1888; since 1888, professor of agricultural physics at University of Wisconsin.

KITCHELL, WILLIAM. Geologist.

Born in East Madison, N. J., April 21, 1827; died, December 29, 1861. Studied medicine, but did not engage in its practice. Taught natural sciences in Newark Institute, and, about 1850, went to Europe and studied in the Mining School at Freiberg, Germany. In 1854–1856, State geologist of New Jersey.

LAPHAM, INCREASE ALLEN. Naturalist.

Born in Palmyra, N. Y., March 7, 1811; died near Oconomowoc, Wis., September, 1876. An all-round scientist and educator; author of many papers on botany, climatology, archæology, cartography, and geology. Chief geologist of Wisconsin, 1873–1875.

Biogr. N. H. Winchell, American Geologist, XIII, 1894, pp. 1–38.

LEA, ISAAC. Conchologist and mineralogist.

Born in Wilmington, Del., March 4, 1792; died in Philadelphia, Pa., December 8, 1886. Trained to mercantile life in Philadelphia, retiring from business in 1851. Was an authority on the Unionidæ, of which he made a very large collection, subsequently willed, together with his large and valuable collection of minerals and gems, to the Smithsonian Institution, in Washington.

Biogr. Pop. Science Monthly, July, 1884, pp. 404–411.
Wm. H. Dall, Some American Conchologists. Proc. Biol. Soc. Washington, IV, 1886–88, pp. 118–120.

LE CONTE, JOHN LAWRENCE. Naturalist.

Born in New York, May 3, 1825; died in Philadelphia, Pa., November 15, 1883. His work was mainly in entomology.

LE CONTE, JOSEPH. Physician and naturalist.

Born on Woodmanston plantation, Liberty County, Ga., February 26, 1823; died in Yosemite, Cal., July 6, 1901. Of Huguenot and Puritan ancestry. In 1845, graduated from College of Physicians and Surgeons in New York and became practicing physician in Georgia. In 1850, studied at Cambridge under Agassiz; in 1852, professor of science at Oglethorpe University, Midway, Ga.; in 1853–1856, professor of natural history at University of Georgia, Athens, Ga.; in 1857–1868, professor of chemistry and geology at South Carolina College, Columbia; in 1869, called to University of California to fill chair of botany, zoology, and geology, remaining there until his death. A voluminous writer on geology and kindred subjects.

Biogr. S. B. Christy, Trans. Amer. Inst. Min. Engs., XXXI, 1902, pp. 765–793.

LEIDY, JOSEPH. Vertebrate paleontologist.

Born in Philadelphia, Pa., September 9, 1823; died in Philadelphia, Pa., August 30, 1891. Educated as a physician, and in 1844, assistant in chemical laboratory of Doctors Hare and J. B. Rogers. In 1846, demonstrator of anatomy in the Franklin Medical College. In 1852, substituted for Doctor Horner as professor of anatomy in the University of Pennsylvania, and in 1853, on the death of Doctor Horner, elected to full professorship. In 1871, appointed professor of natural history in Swarthmore College. Was one of the first Americans to take up the study of vertebrate fossils, and was prominently identified with the early Hayden and other western geological and geographical surveys.

Biogr. E. J. Nolan, Pop. Sci. Monthly, XVII, Sept. 1880, pp. 684–91.

LESLEY, J. PETER. Topographer and geologist.

Born in Philadelphia, September 17, 1819, of Scotch extraction; died in Milton, Mass., June 1, 1903. In 1839–1841, assistant on the State survey of Pennsylvania under H. D. Rogers, mainly in the capacity of topographer. In 1847, became pastor of a Congregational Church in Milton, Mass. This he soon resigned, and thereafter devoted himself to science. Was United States commissioner at the Paris Exposition in 1867. In 1872, professor of geology and dean of faculty in scientific department of the University of Pennsylvania. In 1874, chief geologist of the second geological survey of Pennsylvania.

Biogr. Pop. Sci. Monthly, Sept. 1884, pp. 693–5.
Bull. Geol. Soc. Amer., XV, 1904, p. 532.
Persifor Frazer in American Geologist, XXXII, No. 3, 1903, pp. 132–6.

Lesquereux, Leo. Botanist and paleobotanist.

Born in Fleurier, Neuchatel, Switzerland, November 18, 1806; died in Columbus, Ohio, October 25, 1889. Came to America in 1848 and worked first at Boston with Agassiz and subsequently with Sullivant in Columbus, Ohio. Served as paleobotanist on geological surveys of Pennsylvania, Ohio, Illinois, Kentucky, and Arkansas; also in a similar capacity on the U. S. Geological Survey under F. V. Hayden.

Biogr. Edward Orton, American Geologist, V, 1890, pp. 284–296.
L. R. McCabe in Pop. Sci. Monthly, XXX, Apr. 1887, pp. 835–40; XXXVIII, Dec. 1889, p. 288.

Lieber, Oscar Montgomery. Geologist.

Born in Boston, Mass., September 18, 1830; died in Richmond, Va., June 27, 1862. In 1850–51, State geologist of Mississippi; in 1854–55, State geologist of Alabama; and in 1856–1860, State geologist of South Carolina.

Biog. Lamb's Biog. Dict. of U. S.

Little, George. Geologist.

Born in Tuscaloosa, Ala., February 11, 1838. Graduated from University of Alabama in 1856; professor natural sciences, Oakland College, Mississippi, 1860–61; State geologist of Mississippi, 1866–1872; professor of mineralogy and geology, University of Mississippi, 1866–1874 and 1881–1889; State geologist of Georgia, 1874–1881; professor of geology and agriculture, University of Georgia, 1878–1880.

Litton, Abram. Chemist.

Born in Dublin, Ireland, May 20, 1814; died in St. Louis, Mo., September 23, 1901. Came to America about 1817. For two seasons connected with geological survey under D. D. Owen, and reported on lead mines of southeast Missouri in the Second Annual Report of the State Survey.

Locke, John.

Born in Lempster, N. H., February 19, 1792; died in Cincinnati, Ohio, July 10, 1856. By profession a physician and teacher. In 1835–36, professor of chemistry in the Medical College of Ohio. In 1837–1839, assistant to W. W. Mather on the State geological survey of Ohio. In 1839–1844, assistant to D. D. Owen in the survey of the mineral lands of the United States. In 1847–48, aid to Jackson in surveys of the mineral lands of Michigan. More widely known for his magnetic and astronomical researches than as a geologist.

Biogr. N. H. Winchell, American Geologist, XIV, 1894, pp. 341–56.

Logan, William Edmond. Geologist.

Born in Montreal, Canada, April 20, 1798; died in Castle Malgwyn, Llechryd, South Wales, June 22, 1875. Educated in Scotland and passed his early manhood in England and Wales, but returned to America in 1840. During 1842–1870, director of the geological survey of Canada.

Biogr. B. J. Harrington, Life of Sir Wm. E. Logan, Montreal, 1883. Also Geol. Soc, London and Canadian Naturalist, n. ser., VIII, No. 1, 1875,

Macfarlane, James. Lawyer.

Born in Gettysburg, Pa., September 2, 1819; died in Towanda, Pa., October 12, 1885. Engineer of the North Branch Canal; a leading member of the bar at Towanda; a successful coal operator and railway builder. Author of The Coal Regions of America and An American Geological Railway Guide.

Biogr. I. C. White, American Geologist, VII, 1891, pp. 145–149.

MACLURE, WILLIAM.

Born in Ayr, Scotland, in 1763; died in San Angel, Mexico, March 23, 1840. Came to America at the age of 19 on mercantile business but returned almost immediately to London, where, as partner in the house of Miller, Hart & Co., he remained until 1796, accumulating a considerable fortune. In the last-named year he again came to America and, it is said, took out naturalization papers. He was a liberal patron of science and for twenty-two years, beginning with December, 1817, was president of the Philadelphia Academy of Natural Sciences, to which institution he donated his valuable private library and $25,000 in money.

Biogr. S. G. Morton, Mem. of Wm. Maclure, read July 1, 1841, and published by direction of Philadelphia Academy of Sciences.

MARCOU, JULES. Geologist.

Born in Salins, Jura, France, April 20, 1824; died in Cambridge, Mass., April 17, 1898. Came to America in 1847 and was associated for a time with Louis Agassiz. In 1853 entered United States service and was one of the geologists of the Pacific Railroad Survey of the thirty-fifth parallel, and the author of a geological map of the United States. In 1853 returned to Europe and was professor of geology in the Polytechnic School of Zurich until 1859. In 1860–1864, in charge of division of paleontology of the Museum of Comparative Anatomy, Cambridge.

MARCY, OLIVER. Educator.

Born in Coleraine, Mass., February 13, 1820; died in Evanston, Ill., March 19, 1899. Instructor in mathematics and geology at Wilbraham, Mass., for sixteen years prior to 1862, when he was elected professor of natural sciences in Northwestern University, at Evanston, Ill.

Biogr. A. R. Crook, American Geologist, XXIV, 1899, pp. 67–72.

MARSH, OTHNIEL CHARLES. Vertebrate paleontologist.

Born near Lockport, N. Y., October 29, 1831; died in New Haven, Conn., March 18, 1899. Professor of vertebrate paleontology in Yale College from 1866 to time of death. Vertebrate paleontologist, U. S. Geological Survey, 1882–1899. Honorary curator vertebrate paleontology, U. S. National Museum, 1894–1899. Since 1870 identified with explorations in the West, and chiefly instrumental in bringing together the large and valuable collection of vertebrate remains now in the National Museum.

Biogr. C. E. Beecher, Am. Jour. Sci., VII, 1899, pp. 403–28.

MARVINE, ARCHIBALD ROBERTSON. Geologist.

Born in Auburn, N. Y., September 26, 1848; died in Washington City, March 2, 1876. In 1870, assistant geologist to the Santo Domingo expedition. In 1871, astronomer, and afterwards geologist to the Wheeler surveys west of the one hundredth meridian. In 1872, with Professor Pumpelly in the Keweenaw copper district of Lake Superior, and from 1873 until his death, connected with the U. S. Geographical and Geological Surveys under F. V. Hayden.

Biogr. Pop. Sci. Monthly, IX, 1876, p. 383.
Biogr. J. W. Powell, Bull. Philos. Soc. Washington, II. 1874–1878. Appendix X, p. (53),
G. K. Gilbert, Am. Jour. Sci., XI, 1876, p. 424.

MATHER, WILLIAM WILLIAMS. Geologist.

Born in Brooklyn, N. Y., May 24, 1804; died in Columbus, Ohio, February 26, 1859. Trained at West Point Military Academy. In 1829–1835, assistant professor in chemistry, mineralogy, and geology at that academy. In 1833, professor of geology at Wesleyan University, Middletown, Conn. In 1835, assistant to G. W. Featherstonhaugh. For a short period professor of chemistry, mineralogy, and geology in the University of Louisiana. In 1836–1846, in charge geological survey first district, State of New York. In 1837–1839, State geologist of Ohio, and made geological reconnaissance of Kentucky in 1838–39. In 1842–1850, connected with the Ohio University at Athens, Ohio, in capacity of professor of natural sciences, or vice-president and acting president. Acting professor of geology at Marietta College, 1846. Agricultural chemist to the State and secretary of the State board of agriculture, Ohio, 1850–1854.

Biogr. Lamb's Dict. of the U. S.

MEEK, FIELDING BRADFORD. Paleontologist.

Born in Madison, Ind., December 10, 1817; died in Washington City, December 21, 1876. Assistant to D. D. Owen, surveys of Iowa, Wisconsin, and Minnesota, 1848–49. Assistant to James Hall, 1852–1858. Associated with F. V. Hayden on the Western Surveys beginning with 1853. In 1858, removed to Washington, where he continued to reside until his death.

Biogr. C. A. White, Mem. Nat. Acad. Sci., 1896.

MITCHELL, ELISHA. Naturalist.

Born in Washington, Conn., August 19, 1793; died on Black Mountain, N. C., June 27, 1857. Professor of mathematics, University of North Carolina, 1818 until his death, which was the result of an accident while exploring what is now known as Mount Mitchell in North Carolina. He was an all-round naturalist, and remembered for his works on the geology and general natural history of the State and the Mount Mitchell localities in particular.

Biogr. Journal, Elisha Mitchell, Sci. Soc., I, 1884, p. 6.
Obit. Amer. Journ. Sci. XXIV, 1857, p. 299.

MITCHILL, SAMUEL LATHAM. Naturalist.

Born in North Hempstead, Long Island, August 20, 1764; died in New York City, September 7, 1831. Educated as a physician. In 1792–1801, professor of natural history, chemistry, and agriculture in Columbia College. In 1801–1813, served in Congress. In 1808–1820, professor of natural sciences in College of Physicians and Surgeons, and later professor of materia medica and botany in the same institution. An extremely versatile and gifted man, and one of the founders of the Society for the Promotion of Agriculture, Manufacture, and the Useful Arts, in 1793.

Biogr. H. L. Fairchild, History New York Acad. Sci., 1887, p. 57.

MORTON, SAMUEL GEORGE. Conchologist and paleontologist.

Born in Philadelphia, Pa., January 26, 1799; died in Philadelphia May 15, 1851. Trained for mercantile career. Graduated at University of Pennsylvania in medicine in 1820, and afterwards studied in Europe. Practiced medicine in Philadelphia. His synopsis of organic remains in the Cretaceous formation of the United States gave him scientific reputation. In 1839–1843, professor of anatomy in Pennsylvania Medical College. President, Philadelphia Academy National Sciences in 1849.

Biogr. Wm. H. Dall. Some American Conchologists. Proc. Bio. Soc. of Washington, IV, 1886–8, p. 105.

MUDGE, BENJAMIN FRANKLIN. Chemist and geologist.

Born in Orrington, Me., August 11, 1817; died in Manhattan, Kans., November 21, 1879. Educated as a lawyer. During 1859–60, employed as chemist in oil refineries. In 1864, appointed State geologist of Kansas. In 1865–1873, professor of natural history in the Kansas Agricultural College.

Biogr. S. W. Williston. American Geologist, XXIII, No. 6, 1899, pp. 339–345.

MURRAY, ALEXANDER. Geologist.

Born at Dollerie House, Crieff, in Perthshire, Scotland, June 2, 1810; died there, December 16, 1884. Came to Canada in 1843 as assistant to Logan on geological survey of Canada. From 1864 to 1880, engaged in making geological survey of Newfoundland.

Biogr. Robert Bell. Canadian Record of Science, V, 1882–3, pp. 77–96.

MURRISH, JOHN M.

Born in Cornwall, England, March 8, 1820; died in Mazomanie, Wis., August 17, 1886. Was superintendent of mine in Cornwall. Came to America and settled at Mineral Point, Wis., about 1848. In 1860 removed to Mazomanie, Wis., where he engaged in mercantile pursuits in 1865. In early life a regularly ordained preacher in the Protestant Methodist Church. State geologist of Wisconsin in 1870.

Biogr. Mazomanie, Wis., "Sickle," Aug. 21, 1886.

NEWBERRY, JOHN STRONG. Stratigraphic geologist and paleontologist.

Born in Windsor, Conn., December 22, 1822; died in New Haven, Conn., December 7, 1892. Received degree of M. D. from Cleveland Medical School in 1848. Practiced medicine in Cleveland, 1851–1854. Geologist with Lieutenant Wilkinson's party in Pacific Railroad survey, 1855; with Lieutenant Ives in exploration of Colorado River in 1857; with Captain Macomb's party in Mexico in 1859. From 1866 to the time of his death professor of geology and paleontology in Columbia College, New York City. In 1869–1884, State geologist of Ohio.

Biogr. J. J. Stevenson. Am. Geologist, XII, 1893, pp. 1–26.
J. F. Kemp. School of Mines Quarterly, 1893.
H. L. Fairchild. Hist. N. Y. Acad. Sciences, 1887.

NEWTON, HENRY. Geologist.

Born in New York, August 12, 1845; died in Black Hills of Dakota, August 5, 1877. Graduated from College of City of New York and from Columbia College (School of Mines). In 1869–1876, assistant in metallurgy and geology at Columbia. Assistant geologist of Ohio geological survey and in 1876, assistant engineer on Black Hills expedition. In 1877, was appointed professor of mineralogy and metallurgy in Ohio State University, but did not live to fill that chair.

NILES, WILLIAM HARMON. Geologist and educator.

Born in Northampton, Mass. Educated at Harvard and Yale. Professor of physical geology and geography in the Massachusetts Institute of Technology, 1871–1878; professor of geology and geography, 1878–1902.

NORWOOD, JOSEPH GRANVILLE. Physician and paleontologist.

Born in Woodford County, Ky., December 20, 1807; died in Columbia, Mo., May 6, 1895. Educated as a physician. In 1840–1843, professor of surgery in Madison Medical Institute, Indiana. In 1843–1847, professor of medicine in the St. Louis University. In 1847–1851, assistant geologist with D. D. Owen on the surveys of Wisconsin, Iowa, and Minnesota. In 1851–1858, State geologist of Illinois. In 1858–1860, assistant geologist of Missouri. In 1860–1870, professor of geology, chemistry, and natural sciences in University of Missouri. Writings on geology mainly of a paleontological nature.

Biogr. G. C. Broadhead. Amer. Geol., XVI, No. 2, Aug., 1895, p. 69.

OLMSTED, DENISON. Educator.

Born in East Hartford, Conn., June 18, 1791; died in New Haven May 13, 1859. He was graduated from Yale in 1813. Tutor there, 1815–1817. In 1817, appointed professor of chemistry in the University of North Carolina. In 1824–25, engaged in making a geological and mineralogical survey of North Carolina. During 1825 to 1835, professor of mathematics and natural philosophy in Yale. From 1835 to time of his last illness, professor of natural philosophy and astronomy in Yale. Author of text-books on natural philosophy, astronomy, and meteorology, and perhaps most widely known by his papers on meteoric showers.

Biogr. Am. Jour. Sci. XXVIII, Nov., 1859, pp. 109–118.
New Englander, August, 1859.
Popular Science Monthly, Jan., 1895, pp. 401–408.

ORTON, EDWARD. Geologist.

Born in Deposit, Delaware County, N. Y., March 9, 1829; died in Columbus, Ohio, October 16, 1899. Studied for the ministry and was ordained pastor of the Presbyterian church at Downsville, Delaware County, N. Y. In 1856 he resigned to become professor of natural sciences in New York State Normal School at Albany. Principal of the preparatory department of Antioch College, in Yellowsprings, Ohio, from 1865 to 1872, being elected to the presidency of the college at the latter date. Became president of the State Agricultural College in 1873, which position he occupied until time of his death. Became State geologist of Ohio in 1882. His principal work as an investigator related to the occurrence and origin of petroleum and clays.

Biogr. J. J. Stevenson. Journ. of Geol., VIII, No. 3, 1900, pp. 205-213.
Science, Jan. 5, 1900, pp. 1-12.
Pop. Sci. Monthly, March, 1900, pp. 607-613.
Amer. Geologist, XXV, Apr., 1900, pp. 197-210.
E. O. Hovey. Eng. & Min. Journ., XLVIII, No. 17, Oct. 21, 1899, p. 485.

Owen, David Dale. Geologist.

Born near New Lanark, Scotland, June 24, 1807; died in New Harmony, Ind., November 13, 1860. Came to America in 1824, but returned to Scotland in 1826, returning again to America in 1827. Graduated as doctor of medicine in 1836. Connected with State geological survey of Tennessee under Troost. State geologist of Indiana, 1837-38. Made surveys of the Dubuque and Mineral Point districts of Wisconsin and Iowa, 1839-40. In 1847, was appointed United States geologist, and directed to make survey of the Chippewa land district. In 1854, was appointed State geologist of Kentucky; in 1857, State geologist of Arkansas; in 1859, appointed for the second time State geologist of Indiana.

Biogr. American Geologist, IV, Aug., 1889, pp. 65-72.

Owen, Richard. Educator.

Born in New Lanark, Scotland, January 6, 1810; died in New Harmony, Ind., March 25, 1890. Came to America with his brother, David Dale Owen, in 1827. Was chief assistant to his brother, David Dale, during explorations of northern shore of Lake Superior. For a time professor in Western Military Institute in Kentucky, and the State University in Nashville. Professor of natural sciences in University of Indiana from 1864 to 1879.

Biogr. Pop. Sci. Monthly, XXIII, pp. 109-113; Pop. Sci. Monthly, XXXVII, p. 144.

Peale, Albert Charles. Geologist.

Born in Heckscherville, Pa., April 1, 1849. Graduated from University of Pennsylvania, M. D., in 1871. Mineralogist and geologist, U. S. Geological and Geographical Survey of Territories, 1871-1879; geologist, U. S. Geological Survey, 1881-1898. Since 1898 he has had charge of paleobotanical collections in U. S. National Museum.

Percival, James Gates. Geologist and litterateur.

Born in Kensington, Conn., September 15, 1795; died in Hazelgreen, Wis., May 2, 1856. Received the degree of M. D. in 1820, but never practiced medicine. In 1824, professor of chemistry at the West Point Military Academy. In 1835, was appointed, in company with Prof. C. U. Shepard, to make geological and mineralogical survey of Connecticut. State geologist of Wisconsin, 1854-1856.

Biogr. Am. Journ. Sci., XXII, 1856, pp. 150-1.
Geol. Survey of Wisconsin, 1856. Preface.

Perry, John Bulkley. Clergyman and geologist.

Born in Richmond, Berkshire County, Mass., December 12, 1825; died in Cambridge, Mass., October 30, 1872. Graduated in theology from Andover in 1853, and was preacher until 1867. In that year was appointed lecturer on geology and assistant to Louis Agassiz in paleontology at Harvard. In 1869, lectured on geology in University of Vermont. In 1871, accepted professorship of geology in Oberlin, Ohio.

Hemminways Gazetteer of Vt., for 1904.
Amer. Jour. Sci., IV, 1872, p. 424.

Peter, Robert. Chemist.

Born in Cornwall, England, January 21, 1805; died in Louisville, Ky., 1894. Came to America in 1821. In 1830, professor of chemistry in the Western University of Pennsylvania. In 1832, professor of chemistry in Morrison College, Lexington, Ky. Also served in a similar position in the Transylvania University and in the Kentucky School of Medicine at Louisville. Subsequent to 1865, professor of chemistry in the

Kentucky State College. Was at the head of the chemical department of the State Geological Survey, 1854–1861, and particularly active in the study of soils and mineral waters.

Biogr. Memorial Trans. Ky. State Med. Soc. III, 1895.

POTTER, WILLIAM BLEECKER. Mining engineer and metallurgist.

Born in Schenectady, N. Y., March 23, 1846. Graduated from Columbia, 1866; assistant, geology, Columbia, 1869–1871. Assistant on geological survey of Ohio; professor mining and metallurgy, Washington University, St. Louis, 1871.

POWELL, JOHN WESLEY. Ethnologist and administrator.

Born in Mount Morris, N. Y., March 24, 1834; died in Haven, Me., September 23, 1902. Served through civil war, reaching rank of major. After war, professor of geology in Illinois Wesleyan University and Illinois Normal University. Explored Grand Canyon of Colorado, 1869. In 1871–1879, at head of survey of the Rocky Mountains. In 1879, the Bureau of Ethnology was established and Major Powell made director, a place that he held until his death. In 1881–1894, also director of U. S. Geological Survey.

Wm. H. Brewer. Am. Jour. Sci., XIV, Nov., 1902. pp. 377–382.
Biogr. G. P. Merrill. Am. Geologist, June, '03. pp. 327–333.

PRIME, FREDERICK. Geologist and metallurgist.

Born in Philadelphia, March 1, 1846. Graduated from Columbia College, 1865, A. M. Studied four years at Royal School of Mines, Freiberg, Saxony. Assistant professor Columbia School of Mines, 1869–70; professor geology and metallurgy, Lafayette College, 1870–1879; assistant State geologist of Pennsylvania, 1874–1879; professor natural history, Girard College, since 1895.

PUMPELLY, RAPHAEL. Geologist.

Born in Oswego, N. Y., September 8, 1837. In 1862–63, employed in economic work by Japanese and Chinese Governments. In 1865, appointed professor of mining engineering in Harvard University. In 1869–1871, State geologist of Michigan, and, 1872–73, director of State survey of Missouri. In 1881, director northern transcontinental survey, and, 1884–1890, in charge archean division of the U. S. Geological Survey.

Biogr. Nat. Cyclopedia, VI, p. 362.

REDFIELD, WILLIAM C. Meteorologist.

Born near Middletown, Conn., March 26, 1789; died in New York City, February 12, 1857. Wrote principally on meteorology, being the author of some 62 papers on this subject. Also wrote articles on geology, with particular reference to the eastern Triassic areas.

Biogr. Am. Jour. Sci., XXIII, 1857, pp. 292–293; XXIV, 1857, pp. 355–373; Canadian Nat. & Geol., II, 1857, pp. 426–446.
H. L. Fairchild. History of New York Academy of Science, 1887, pp. 76–81.

ROEPPER, WILLIAM T. Mineralogist.

Born in Peilau, Lower Silesia, March 7, 1810; died in Bethlehem, Pa., March 11, 1880. Came to America in 1840 in the service of the Moravian Church. In 1866, was appointed professor of mineralogy and geology and curator of museum in Lehigh University, Bethlehem, Pa., retaining the professorship for three years, but remaining curator until 1871. His writings were mostly of a mineralogical nature.

Biogr. Am. Jour. Sci., XIX, 1880, p. 340.

ROGERS, HENRY DARWIN. Geologist.

Born in Philadelphia, August 1, 1808, and died near Glasgow, Scotland, May 29, 1866. Professor of chemistry and natural philosophy in Dickinson College, 1830–31. Professor of geology and mineralogy in University of Pennsylvania, 1835–1846. State geologist of New Jersey, 1835–1840; State geologist of Pennsylvania, 1846–1852; regius professor of natural history in University of Glasgow, Scotland, 1857–1866.

ROGERS, WILLIAM BARTON. Geologist and educator.

Born in Philadelphia, Pa., December 7, 1804; died in Boston, Mass., May 30, 1882. Professor in William and Mary College, 1827–1835. Professor of natural history, University of Virginia, 1835–1853. Director of the geological survey of Virginia, 1835–1842. One of the founders and president of the Massachusetts Institute of Technology, 1862 to the time of his death. President of American Association for the Advancement of Science in 1875.

Biogr. Pop. Sci. Monthly, IX, 1876, pp. 606–611.
Life and Letters of W. B. Rogers, The Riverside Press, Cambridge, Mass.

ROMINGER, CARL LUDWIG. Physician and paleontologist.

Born in Schnaitheim, Wurttemberg, Germany, December 31, 1820. Graduated from University of Tübingen in 1839. Assistant in chemical laboratory of same university, 1842–1845. In 1845–1848, studied geological structure of various countries of Europe. Came to United States in 1848 and practiced medicine in Cincinnati for twenty-five years. In 1870–1883, director of the geological survey of Michigan.

RUFFIN, EDMUND. Agriculturist.

Born in Prince George County, Va., January 5, 1794; died, June 17, 1865. Wrote principally on soils and manures. For a time agricultural surveyor of South Carolina.

RUSSELL, ISRAEL COOK. Geologist and geographer.

Born in Garrattsville, N. Y., December 10, 1852. Graduated from New York University. Postgraduate studies in School of Mines, Columbia. Member U. S. Transit of Venus expedition to New Zealand, 1874–75; assistant in geology, Columbia, 1875–1877; assistant geologist on U. S. Geological and Geographical Survey west of one-hundredth meridian, 1878; geologist U. S. Geological Survey, 1880–1892; professor of geology, University of Michigan, since 1892.

SAFFORD, JAMES MERRILL. Geologist.

Born in Putnam (now Zanesville), Ohio, August 13, 1822. Graduated from Ohio University, at Athens, in 1844. Professor of natural science at Cumberland University, Lebanon, Tenn., from 1848 to 1872. State geologist of Tennessee, 1854–1860 and 1871–1889. For twenty-five years professor of geology in Vanderbilt University, 1875–1900.

SCHOOLCRAFT, HENRY ROWE. Explorer.

Born in Albany County, N. Y., March 28, 1793; died in Washington City, December 10, 1864. Was trained as land surveyor and became early connected with western exploring expeditions. Was naturalist and mineralogist on the expedition to explore the sources of the Mississippi River and investigate the copper deposits of Lake Superior, 1820–1822. Traveled extensively in central portions of the Mississippi Valley in 1824–25. In charge of an expedition to upper Mississippi Valley in 1832. Best known as traveler and explorer, but his notes contain much material which at the time was of geological interest and importance.

Biogr. Pop. Sci. Monthly, May, 1890, pp. 113–121.
National Magazine, Jan. 1855.

SCUDDER, SAMUEL HUBBARD. Entomologist and paleontologist.

Born in Boston, Mass., April 13, 1837. Graduated from Williams College, 1857; Lawrence Scientific School, B. S., 1862. Assisted Louis Agassiz in Museum of Comparative Zoology, Harvard, 1862–1864; secretary Boston Society of Natural History, 1862–1870; president of same, 1880–1887. Paleontologist, U. S. Geological Survey. Voluminous writer on living and fossil insects.

SELWYN, ALFRED RICHARD CECIL. Stratigraphic geologist.

Born in Kilmington, Somersetshire, England, July 28, 1828; died in Vancouver, British Columbia, October 19, 1902. Assistant geologist on geological survey of Great Britain from 1845 to 1852. In 1853, appointed to undertake geological survey of Victoria, Australia; also made report on Tasmanian coal and gold fields, and in

1859, made survey of South Australia. In 1869, succeeded Sir William Logan as director of geological survey of Canada. In 1871, undertook exploring expedition into British Columbia. His publications number more than eighty books and pamphlets on geological subjects.

Biogr. Henry Woodward. Geological Magazine, London, Feb., 1899, pp. 49–55.
H. M. Ami. American Geologist, XXXI, No. 1, Jan. 1903, pp. 1–21.

Shaler, Nathaniel Southgate. Geologist and educator.

Born in Newport, Ky., February 20, 1841. Graduated from Harvard in 1862. Instructor zoology and geology Lawrence Scientific School, 1868–1872; professor paleontology, 1868–1887, and since then professor geology, Harvard University; director, Kentucky geological survey, 1873–1880.

Shepard, Charles Upham. Mineralogist.

Born in Little Compton, R. I., June 29, 1804; died in Charleston, S. C., May 1, 1886. Graduated from Amherst College in 1824. Assisted Professor Silliman at Yale College, 1827–1845. State mineralogist of Connecticut, 1835–1837; 1845–1852; and 1861–1877, professor of chemistry and natural history in Amherst College, Massachusetts. During 1854–1861 and 1865–1869, professor of chemistry at South Carolina Medical College, Charleston.

Biogr. Am. Journ. Science, XXXI, 1886, p. 482.

Shumard, Benjamin Franklin. Paleontologist.

Born in Lancaster, Pa., November 24, 1820; died in St. Louis, Mo., April 14, 1869. Educated as a physician, but early became interested in paleontology. Contributed to Owen's Report on the Geology of Wisconsin, Iowa, and Minnesota. In 1850, accompanied Doctor Evans on his geological reconnaissance of Oregon. In 1853, was appointed assistant geologist and paleontologist of the Missouri geological survey under G. C. Swallow. State geologist of Texas, 1858–1861. His work was almost wholly of a paleontological nature.

Biogr. Amer. Geol., IV, No. I, July, 1899, pp. 1–6.
Am. Journ. Science and Arts, XLVIII, 1869, p. 294.

Silliman, Benjamin. Chemist and educator.

Born in New Stratford (now Trumbull), Conn., August 8, 1779; died in New Haven, Conn., November 24, 1864. Professor of chemistry and natural history at Yale College, New Haven, Conn., 1802–1853. Founded the American [Silliman's] Journal of Science in 1818. Was noted as teacher, public lecturer, and writer more than an original investigator.

Am. Journ. of Science and Arts, XXXIX, May, 1865, p. 1.
George P. Fisher. Life of Benjamin Silliman, N. Y., Scribner & Co., 1866.
Memoir of Benjamin Silliman by Alexis Caswell. Mem. Nat. Acad. of Sci., I, 1877.
Biogr. Pop. Sci. Monthly, XXIII, June, 1883, pp. 259–266.

Silliman, Benjamin, Jr. Chemist.

Born in New Haven, Conn., December 4, 1816; died in New Haven, January 14, 1885. In 1837–1846, assistant professor, and 1837–1885, professor of chemistry at Yale College.

Smith, C. D. Clergyman.

Born in Buncombe County, N. C., April 1, 1813. By profession a Methodist clergyman, but during a portion of 1859 and 1860 was connected with the geological survey of North Carolina under Ebenezer Emmons. Was also for a time connected with the State survey under W. C. Kerr.

Smith, Eugene Allen. Geologist.

Born in Washington, Autauga County, Ala., October 27, 1841. Graduated from University of Alabama, 1862. In 1865–1868, studied in Germany, returning to America and becoming assistant to Dr. George Little on geological survey of Mississippi. In 1871 became professor of geology and mineralogy in University of Alabama, and in 1873 was appointed State geologist, which position he still holds.

SMITH, JOHN LAWRENCE. Mineralogical chemist.

Born in Charleston, S. C., December 17, 1818; died in Louisville, Ky., October 12, 1883. Practicing physician in Charleston, S. C., and State assayer for North and South Carolina. Mining engineer to the Turkish Government, 1846-1850. Commissioner to Paris Exposition in 1867. Published many papers on the chemical composition of American minerals and was an authority on the subject of meteorites.

Biogr. Pop. Sci. Monthly, VI, Dec. 1874, pp. 233-236.
Biogr. Benj. Silliman. Nat. Acad. Sci., Biogr. Memoirs. II, 1886.

SQUIRE, JOSEPH. Mining engineer.

Born in England. Came to America at age of 18. Employed in works of Peabody Furnace Company, at Providence, R. I., where he learned mining. Subsequently moved to Kansas. In 1859, went to Alabama and became engaged in coal mining and the work of a mining engineer. After 1879 was employed part of the time by State geological survey.

STEVENSON, JOHN JAMES. Geologist and educator.

Born in New York City, October 10, 1841. Graduated from New York University in 1863. United States geologist, 1873-74; with Wheeler survey west of one-hundredth meridian, 1878-1880; geologist of Pennsylvania geological survey, 1875-1878, 1881-82; professor of geology, New York University, since 1871.

SWALLOW, GEORGE CLINTON. Stratigraphic geologist.

Born in Buckfield, Oxford County, Me., in 1817; died at Evanston, Ill., April 20, 1899. Lecturer on botany as applied to agriculture and mechanical arts at Bowdoin College, 1843; principal of Brunswick Female Seminary, 1843-1849; principal of Hampden Academy, Maine, 1849; professor of chemistry, geology, and mineralogy of the University of the State of Missouri, 1851-1853; State geologist of Missouri, 1853-1861; professor of chemistry and natural science in the University of Missouri, 1857-58; assistant geologist of Kansas, 1864; State geologist of Kansas, 1865-66; professor of agriculture in the Agricultural and Mechanical College of Missouri, 1870; professor of botany, comparative anatomy, and physiology in medical school of University of Missouri, 1872; professor of natural sciences and dean of the Agricultural and Mechanical College up to 1882; State inspector of mines of Montana, 1888-89.

Biogr. American Geologist, XXIV, July, 1899, pp. 1-6.

TAYLOR, RICHARD COWLING. Geologist and mining engineer.

Born in Hinton, Suffolk, England, January 18, 1789; died in Philadelphia, Pa., October 26, 1851. Came to America about 1830.

TESCHEMACHER, JAMES ENGLEBERT. Paleobotanist.

Born in Nottingham, England, June 11, 1790; died in Boston, Mass., 1853. Came to America February 7, 1832, and settled in Boston. A business man with scientific tendencies.

THOMPSON, ZADOCK. Clergyman.

Born in Bridgewater, Vt., May 23, 1796; died in Burlington, Vt., January 19, 1856. First became noted as a compiler of almanacs and from his publication of a gazetteer of Vermont, which appeared in 1826. Assistant on State geological survey of Vermont, 1845-1847. State naturalist of Vermont, 1853-1856.

Biogr. Pop. Sci. Monthly, Dec., 1904, pp. 262-267.
Am. Journ. Sci., XXII, 1856, pp. 44-49.
G. H. Perkins. American Geologist, XXIX, No. 2, 1902, pp. 65-71.

TRASK, JOHN BOARDMAN. Surgeon.

Born in Roxbury, Mass., 1824; died in San Francisco, Cal., July 3, 1879. Educated at Yale. One of the charter members of the Academy of Natural Sciences of San Francisco. Geologist on boundary survey between Mexico, California, and Nevada; State geologist of California in early fifties. Assistant surgeon of volunteers in civil war.

A. W. Vogdes, San Diego, Cal,

TROOST, GERARD. Chemist and geologist.

Born in Bois-le-Duc, Holland, March 15, 1776; died in Nashville, Tenn., August 14, 1850. Came to the United States in 1810 and was one of the founders of the Philadelphia Academy of Natural Sciences in 1812; chosen its first president. In 1821, was appointed professor of mineralogy in Philadelphia Museum, and professor of chemistry in the Philadelphia College of Pharmacy. Professor of chemistry, geology, and mineralogy in University of Nashville, Tenn., 1828–1850. State geologist of Tennessee, 1831–1850.

Biogr. Appleton's Cylo. of Amer. Biog.
L. C. Glenn. Amer. Geol., XXXV, No. 2, 1905, pp. 72–94.

TUOMEY, MICHAEL. Geologist.

Born in Cork, Ireland, September 29 (St. Michael's Day), 1805; died in University, Ala., March 30, 1857. Came to America when about 17 years of age and became a teacher on the eastern shore of Virginia, but afterwards went to Troy, N. Y., and was graduated from Rensselaer Institute. State geologist of South Carolina in 1844. In 1847, was appointed professor of geology, mineralogy, and agricultural chemistry in the University of Alabama, and in 1848, was appointed State geologist without salary. In 1854, relinquished his professorship at the University in order that he might give all his attention to the survey.

Biogr. Amer. Geol., XX, Oct. 1897, pp. 205–212.

TYSON, PHILIP THOMAS. Chemist.

Born in Baltimore, Md., June 23, 1799; died there December 16, 1877. State agricultural chemist of Maryland 1858.

VAN RENSSELAER, STEPHEN. Patron.

Born in New York City, November 7, 1765; died in Albany, N. Y., January 26, 1839. Established the Rensselaer Polytechnic Institute in Troy, N. Y., in 1826. A general patron of the sciences and the pioneer of American geological surveys, Eaton's early work on the geology of the Erie Canal region being carried on at his expense.

Biogr. Amer. Jour. Sci., XXXVI, 1839, pp. 156–164.

VANUXEM, LARDNER. Chemist and stratigrapher.

Born in Philadelphia, Pa., July 23, 1792; died in Bristol, Pa., January 25, 1848. Professor of chemistry and geology in Columbia College, S. C., from 1820 to 1826. In charge of third district New York survey from 1836–1842.

Biogr. Pop. Sci. Monthly, April, 1895, pp. 833–840.

WACHSMUTH, CHARLES. Paleontologist.

Born in Hanover, Germany, September 13, 1829; died in Burlington, Iowa, February 7, 1896. Came to America in 1852 and entered upon a mercantile career, but going West for his health took up scientific pursuits, in which he continued until his death. For several years assistant to Louis Agassiz in the Museum of Comparative Zoology.

Biogr. Chas. R. Keyes in American Geologist, XVII, 1896, pp. 131–136.

WALCOTT, CHARLES DOOLITTLE.

Born in New York Mills, N. Y., March 31, 1850. Became assistant, New York State survey, 1876. Connected with U. S. Geological Survey, as geologist and paleontologist since 1879, and as Director since 1894. From January, 1897, to July, 1898, Acting Assistant Secretary of Smithsonian Institution. The Cambrian rocks and faunas of the United States have been his especial subjects of research.

WHITE, CHARLES ABIATHAR. Paleontologist and stratigrapher.

Born in North Dighton, Mass., January 26, 1826. Graduated from Iowa College. State geologist of Iowa, 1866–1870; professor Iowa State University, 1867–1873; professor Bowdoin College, Maine, 1873–1875; geologist and paleontologist to various United States Government surveys, 1874–1892. Connected with the U. S. National Museum since 1876.

WHITE, ISRAEL C. Geologist.

Born in Monongalia County, W. Va., November 1, 1848. Graduated from West Virginia University, 1872, A. M.; assistant geologist, Second Geological Survey, Pennsylvania, 1875–1884; on U. S. Geological Survey, 1884–1888; professor of geology, West Virginia University, 1877–1892. Specialist in coal, petroleum, and natural gas. State geologist of West Virginia since 1897.

WHITFIELD, ROBERT PARR. Paleontologist.

Born in New Hartford, Oneida County, N. Y., May 27, 1828. Assistant in paleontology on New York State natural history survey, 1856–1876; U. S. Geological Survey, 1872; teacher and professor of geology, Rensselaer Polytechnic Institute, Troy, N. Y., 1872–1878; since 1877, curator of geological department, American Museum Natural History.

WHITNEY, JOSIAH DWIGHT. Geologist.

Born in Northampton, Mass., November 23, 1819; died in New London, N. H., August 19, 1896. Graduated at Yale, 1839. In 1840–1842, assistant to Jackson in geological survey of New Hampshire. In 1847–1851, on survey of mineral lands of Lake Superior district. In 1855, appointed State chemist of Iowa and professor in State University. In 1858–59, associated with James Hall on geological survey of Iowa. In 1858–1860, with Hall on geological survey of Wisconsin. In 1860–1874, State geologist of California. From 1865 to his death, the Sturgis Hooper professor of geology, Harvard University, Cambridge, Mass.

WHITTLESEY, CHARLES. Stratigraphical geologist and archæologist.

Born in Southington, Conn., October 4, 1808; died in Cleveland, Ohio, October 18, 1886. Graduated from West Point in 1831; resigned from army at close of Black Hawk War, and from that time to 1837 practiced law. In 1837–1839, assistant to W. W. Mather in survey of Ohio, acting as topographer, geographer, and geologist. In 1844, geologist in exploration of copper region of Michigan. In 1847–1851, employed in United States survey of country around Lake Superior and upper Mississippi with reference to mines. In 1849, 1850, 1858, explored valley of Menominee River and north shore of Lake Superior. In 1848, connected with D. D. Owen's survey of northern Wisconsin. In 1858–59, made geological surveys of Wisconsin, and in 1860, assisted James Hall in survey of same State. From 1867 to time of death, devoted to promotion of Western Reserve and Northern Ohio Historical Society, of which he was president; voluminous writer on geology and archæology of Northwest.

Biogr. A. Winchell, American Geologist, IV, 1889, pp. 257–68.

WIGHT, O. W. Physician.

State geologist of Wisconsin 1875, succeeding Lapham, and himself succeeded by Chamberlain. Made but one report.

WINCHELL, ALEXANDER. Geologist and educator.

Born in Northeast, N. Y., December 31, 1824; died in Ann Arbor, Mich., February 19, 1891. Began life as a teacher. On October 5, 1850, took charge of an academy at Newbern, Greene County, Ala. In 1851, opened the Mesopotamia Female Seminary in Eutaw, Ala. In 1853, became president of the Masonic University at Selma, Ala. On November 16, 1853, was appointed professor of physics and civil engineering in the University of Michigan, entering upon his duties January 24, 1854. In 1855, became professor of geology, zoology, and botany in the university. State geologist of Michigan, 1859–1861 and 1869–1871. Chancellor of Syracuse University, 1873–74; professor of geology, Syracuse University, 1874–75. Connected with Vanderbilt University, in Nashville, Tenn., 1875–1878. Professor of geology and paleontology in Ann Arbor, Mich., 1879–1891. Professor Winchell was one of the best known of popular writers and lecturers in geology.

Bull. Geol. Soc. of America, III, 1891, pp. 3–13, 56–59.
Amer. Geol., IX, 1892, pp. 71–148.

Winchell, Newton Horace. Geologist.

Born in Northeast, N. Y., December 17, 1839. Employed on geological survey of Michigan in 1860; graduated from University of Michigan, 1866; assistant State geologist of Michigan, 1869–70; assistant geological survey Ohio, 1870–1872; editor American Geologist, Minneapolis; professor of mineralogy and geology, University of Michigan, and State geologist, 1872–1900.

Wing, Augustus. Clergyman and teacher.

Born in Rochester, Vt., November 19, 1808; died in Whiting, Vt., January 19, 1876. Educated as a clergyman, but soon left the profession to become a teacher and investigator. Published practically nothing, but made very exhaustive studies of the limestone, slates, and quartzites of the Otter Creek Valley, with a view of settling their geological age. His results were communicated to Dana, who utilized them in his papers upon the Taconic question.

Biogr. American Geologist, XXVIII, 1901, pp. 1–8.

Wislizenus, Frederick Adolphus. Physician.

Born in Koenigsee, in Schwarzburg-Rudolstadt, Germany, May, 1810; died in St. Louis, Mo., September 22, 1889. Graduated from University of Zurich in 1834. Came to America in 1837, settling in St. Louis. His geological work chiefly result of expedition into Mexico, report of which appeared in Washington in 1848.

Worthen, Amos Henry. Paleontologist.

Born in Bradford, Orange County, Vt., October 31, 1813; died in Warsaw, Ill., May 6, 1888. Began life as a merchant at Warsaw, Ill. Assistant to J. G. Norwood, State geologist of Illinois, in 1853. Assistant to Prof. James Hall, State geologist of Iowa, 1855–1857. State geologist of Illinois from 1858–1888, and curator of the State Natural History Museum from 1877. His work was mainly of a paleontological and stratigraphic nature, and related principally to the Carboniferous series.

Biogr. Chas. A. White, Mem. Nat. Acad. Sci., Nov. 1893, pp. 341–362.
E. O. Ulrich, American Geologist, Aug. 1888, pp. 114–117.

Wright, Charles E. Geologist.

Born in Copenhagen, Lewis County, N. Y., October 7, 1843; died in Marquette, Mich., March 22, 1888. Began life as a civil engineer, afterwards turning his attention to geology and mining engineering. Commissioner of mineral statistics for Michigan, 1876–1883. State geologist of Michigan, 1884–1888. His work was limited mainly to the mining regions of northern Michigan.

Biogr. American Geologist, II, 1888, pp. 307–312.

Wright, George Frederick. Clergyman and glacial geologist.

Born in Whitehall, N. Y., January 22, 1838. By profession a clergyman, and in 1871 pastor of a Congregational church in Andover, Mass. In 1881, professor of New Testament Exegesis in Oberlin Theological Seminary. Has written extensively on glacial subjects, his most pretentious work being his Ice Age in North America.

Wurtz, Henry. Chemist.

Born in eastern Pennsylvania, June 5, 1828. Graduated from Princeton in 1848. In 1851, became instructor in Yale scientific school. In 1853–1855, chemist of the geological survey of New Jersey.

Wyman, Jeffries. Anatomist and vertebrate paleontologist.

Born in Chelmsford, Mass., August 11, 1814; died in Bethlehem, N. H., September 4, 1874. Graduated from Harvard in 1833 and studied and practiced medicine. Professor of anatomy and physiology at Hampden Sidney College at Richmond, Va., 1843–1847. From 1847 to time of his death, Hersey professor of anatomy at Harvard College, Cambridge.

Biogr. A. S. Packard, Nat. Acad. Sci., Biog. Memoirs, II, 1886.

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