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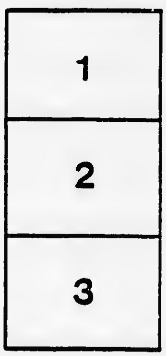
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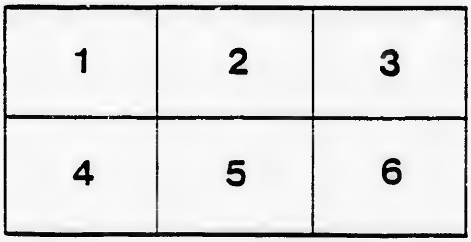
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Lyell's Lectures on Geology.

EIGHT

LECTURES ON GEOLOGY,

Delivered

AT THE BROADWAY TABERNACLE IN THE CITY OF NEW-YORK,

BY CHARLES LYELL, F. R. S.
VICE PRESIDENT OF THE GEOLOGICAL SOCIETY OF LONDON, ETC.

FRESH WATER FORMATIONS OF AUVERGNE; EXTINCT VOLCANOES OF SUCCESSIVE PERIODS.
STRUCTURE OF ÆTNA; ORIGIN OF GRANITIC ROCKS; CHANGES IN THE ORGANIC WORLD.
UPHEAVAL AND SUBSIDENCE OF THE EARTH'S CRUST; SUBMERGENCE AND RE-ELEVATION OF THE TEMPLE OF SERAPIS.
ORIGIN OF CORAL REEFS, AND THEORY OF THEIR CIRCULAR FORM; CORALINE LIMESTONE OF VARIOUS GEOLOGICAL AGES.
NATURE AND ORIGIN OF COAL; PERIOD OF ITS FORMATION.
FOOT-MARKS OF FOSSIL ANIMALS; THE NIAGARA DISTRICT.
CHIROTHERIUM ORGANIC REMAINS OF THE MOST ANCIENT ROCKS.
RECESSION OF THE FALLS OF NIAGARA.
BOULDER FORMATION; TRANSPORTING POWER OF ICE; ACTION OF GLACIERS AND ICEBERGS.

REPORTED FOR "THE NEW-YORK TRIBUNE."

NEW-YORK:
GREELEY & McELRATH, TRIBUNE OFFICE.
1842.

ADVERTISEMENT.

The Eight Lecture on Geology here submitted to the public are substantially these which have been delivered by Mr. LYELL before large and respectable audiences in the principal Cities of the Union. They present the conclusions to which Geologists have been led by the most recent Discoveries and Researches in that Science, by explorers in both hemispheres, including those who have labored in the employment of our several States They may therefore be justly regarded as additions to the sum of Geological knowledge conveyed in preceding publications, and as such valuable to the man of Science no less than to the inquirer and student. They were reported for The New-York Tribune, as delivered at the Tabernacle, by Mr. H. J. RAYMOND, Assistant Editor of that paper, whose Reports of Dr. LARDNER'S and other Scientific Lectures have already been received with decided and merited approbation. They have been carefully revised and prepared for this edition, which the publishers confidently trust will be found worthy of equal favor.

New-York, April 13, 1842.

LECTURES ON GEOLOGY.

LECTURE I.

Mr. LYELL opened his Lecture by saying that he had been invited to give a short course of lectures upon one of the most extensive branches of Natural Science; and as he was to have but a few meetings, he should lose no time in prefatory remarks, but would proceed at once to the subject and endeavor as well as he could to enable his class to comprehend the objects of Geology, the means of proof employed, and in what manner we attempt to interpret those monuments we term geological. If any one should ask him in what way he could soonest arrive at an understanding of the subject so far as eight meetings would allow, he should take him at once into the field of observation. I should go, said he, up this magnificent river—the Hudson—and point you first to the Palisades, which you can see from this City; I would show you the natural rock, called Basalt, with its columnar structure, and explain the reasons why we conclude that these rocks thus piled up have existed in a melted state in the interior of the Earth. I would show you the other rocks—as the Sandstone, which was once sand until it was consolidated—deposited, one above another, under the water until a flood of melted matter flowed over and made it solid. Going still farther up, I would show you the gneiss and granite of the Highlands; or I might come back to this very island on which New-York is situated.

But as it is impossible thus to carry you into the field, the next best thing I can do is to show you some representation of natural scenes, and explain their several parts. The scene to which I first call your attention is one of the most remarkable known in Europe—far more striking than any I have seen in the British Isles. The series of geological phenomena, here exhibited, all belong to the same great class of rocks, but it is easy for the merest novice to see that they belong to different periods: their origin is to be referred to distinct epochs and to dissimilar causes. This is a scene of *Auvergne*. Having visited all the portions of it I can vouch for the accuracy of the geological representation which is enlarged from a drawing by my friend Mr. SCROPE. To understand the geographical position of the region it will be necessary to refer you to a map of France. What is called the Paris Basin is a strata of comparatively modern origin: nearly two hundred miles South of Paris are situated the Extinct Volcanoes, of which the principal mass is Mount Dor, which is in the centre of the granite region—its rocks being of marine origin. And here let me say that by rocks we mean technically in Geology any set of mineral masses whether hard or soft—whether loose like sand or consolidated like granite—soft clay as well as hard shale. These rocks contain a variety of shells and corals, called marine as having been formed originally beneath the sea. This is the zone of the granite region in France. Mount Dor, which is near Clermont, is more than 150 miles South of Paris.

The next scene I shall show you is a vertical section of this region—just as if you should dig a railway—the rocks being represented to a certain depth, as far as half a mile, as though they were cut down vertically, just as you may see in a line of sea cliff. The upper portion is of basalt—similar to the Palisades—and the lower is of a different kind of volcanic rock—a Feldspar rock called Trachyte. As it would be impossible for you to follow me were I to attempt it, I shall not enter upon any detailed explanation of these terms. It may be well to say that more rocks are found in this mountain than could be represented in a drawing. There is a great prevalence of Feldspathic rocks and of heavier basaltic rocks containing a dark mineral called augite. You see the granite represented below the volcanic rocks as we have abundant evidence for thus representing it in that section. You see the granite peeping out from the Trachyte; we find dykes of other kinds of lava passing through the granite and then joining into sheets of lava, as we may call them, which we know once flowed in a melted stream.

We have the granite then as the fundamental rock: then come the different kinds of volcanic rocks: then at a greater distance the stratified rocks, which we know are of fresh water origin—formed at the bottom of lakes which have now disappeared just as the fires of the volcanoes are now extinct. The basalt appears, as I have said, in precipitous cliffs divided into vertical columns like the Palisades. In another portion is a mass of white calcareous marl abounding in shells and not far off is a smaller cone—a mass of volcanic matter of later date than the other. After the volcano had poured forth its lava until it had piled up a mountain 3,000 feet high, and a valley had been cut down to the subjacent granite through a great series of volcanic rocks, and after the lake had been drained by a river called the Coos, then there happened another volcanic eruption from the volcano called Puy de Tartaret similar to the one which was formed in the Bay of Baiae which it resembles in structure and size. Now when this was thrown up (which is but a type of a hundred similar cones in that part of France,) it stopped up the course of the Coos—blocking it up so as to produce a lake which once extended much farther for the alluvial matter which was carried into it formed a large Delta which greatly curtailed its boundaries. At the same time that the volcano bursted forth in the midst of this ancient valley out flowed streams of lava from the other side, which you may see passing at the base of the hill on which the castle of Muro stands. Flowing down the valley for thirteen miles in a narrow stream it dispossessed the river of its ancient bed as has been the case in Iceland within the last century, when streams of lava have flowed from the sides of Hecla and Skapta Jokul and forced rivers to flow aside from their usual beds. So out of this flowed a stream which took its course along the base of the hills, cutting its way through the fresh water formations.

It is a matter of proof that these strata are really of fresh water formation—that they were formed in ancient lakes where were left valleys after the draining of the lakes, and that through the bottom of these flowed the lava. Thus we may trace the cappings up to Mount Dor, the ancient and grand centre of the first eruption. From this the higher cappings of basalt were produced; and to cause these phenomena and cut through the valleys so as to allow other valleys to be formed, how great a series of changes and how long a chronological order of events is implied! The hight of Mount Dor above the level of the sea is 7000 feet, and we can look back to the time when that country was only 3000 feet above the sea, and consisted exclusively of the fundamental granite. At that time we find there were depressions in which there were a number of lakes extending all the way from Paris to the source of the river Loire. That was the first state of things, and the mountains were featureless in appearance—with round swells but with no picturesque, uneven outline—and into the lakes sediment was carried by rivers, and the beds, of which I shall soon speak, were accumulated. Then came a period of the draining of the lakes, and then the excavation of the valleys; just as we have on the borders of Lake Superior and other Northern lakes, where the rocks are granite. If Earthquakes should occur and shake that region and alter the level of the country, the lakes would be drained and we should have the second state of things as in this part of France. If we follow the volcanic eruptions in the same district until the lava was piled 3000 feet high, we should have the third period. If floods should produce deep valleys, and a new set of volcanoes should form small mountains at the bottom of the valleys, we should have the fourth period. The fifth period would arrive when rivers should have eaten out deep chasms even in the most modern lava, and formed precipices some two hundred feet high—which would involve a period of considerable duration.

While great changes are going on in the inanimate world others no less interesting are produced in the animate world; for we see entire fluctuations in quadrupeds and other beings which successively inhabit the region. It is impossible to represent in a picture, in their proper proportions, the hight of the various parts of the country. The fresh water formations do not appear sufficiently in depression to give the proper appearance of the ancient lakes.

There is no doubt that the superior upheaval of the Southern part of the country was what caused the drainage of the Lake and the excavation of the valleys which are cut through them, producing what is called the Lacustrine formation. If we simply take for granted the upheaval of the whole district, (which need surprise no one, for we shall have occasion to show that far more extensive upheavals above the level of the sea, are *now* going on;) we need only suppose a series of movements such as are demonstrated to have taken place, to have raised the Southern portion at a greater rate than the Northern, to find an easy explanation for those geographical phenomena.

I have now stated that cotemporaneously with these mighty changes, physical and geographical, there went on a series of revolutions in organic life. I am not going to enter in the present lecture upon the difficult problem of the origin of granite. We must take the granite as it exists in the country. Hills are made of it, and lakes have been hollowed out of it. I will come at once, then, to the Lacustrine period. The lakes were inhabited by a different set of shell-fish, of moluscular animals, water-birds, crocodiles and turtles from any that now exist in that part of France. There are now no such animals as once abounded in the ancient lakes of Auvergne. We find their remains well preserved in the various strata. The tortoise which then existed is not now to be found. I may remark, too, that there have been discovered the skeletons of some thirty or forty quadrupeds to which CUVIER gave as many different names, as the Palæotherium, Anoplotherium, &c., which need not be mentioned. The Palæotherium is an intermediate species between the Tapir and the Rhinoceros, and the Anoplotheria has some relation to the same animals, and also to the hog tribe. There are also several species of animals found in the neighborhood of Paris, which now exist—*though not in that region*—as, for instance, the species of Opposum, which now exists only in this country and Australia. On the whole, there are about fifty species of quadrupeds discovered, some of which are as large as the Rhinoceros. I need not say that a single jaw, or even sometimes a single tooth, is quite sufficient in the hands of a Naturalist to decide the species of these Mammalia. These animals were undoubtedly washed down by the swelling of the rivers, just as they are liable to be now. We have no hesitation in saying that these fifty species of quadrupeds have now passed away from the globe. Some might doubt our ability to say this; but a little consideration of the fossils found will be sufficiently convincing. I have procured drawings of one or two shells which are there found—as, for instance, the *Planorbis*, which abounds at present in the lakes of North America, and which once existed in the lakes of France, and are now found in the strata. The *Valvata*, a fresh-water shell which is common here and in Europe, was also to be met in the old Lacustrine formation of France. Any naturalist will be easily convinced that these shells are now extinct in that region, and no one will be so skeptical as not readily to grant that we are safe in saying that the Palæotherium, the Megatherium, and many other large quadrupeds which CUVIER discovered and compared, are now lost, and have been permitted by the Author of Nature to die out from the globe. This is the first state of the ancient world of this region, to which we are carried back by the geological monuments of this scene.

The next period of the ancient volcanic rocks of Mount Dor was when they produced a perfectly distinct race of quadrupeds, of which I believe only one has been found to resemble those of the former period. All the genera are different, and almost all of this period are of existing genera, but not to be found in that part of Europe. We find the rhinoceros, the elephant, the hippopotamus, the bear, and others, which never within historical times have peopled that cold region. The beaver which is found is not the same as that now common to Europe and North America, and so with a vast multitude of others.

But you may ask how we should have these fossils remaining in volcanic rocks—how they could be preserved if they were enfolded in a sheet of red-hot matter as from a furnace? It is easy to explain how this might happen. In all volcanoes, where the lavas are feldspathic, there are great floods; lakes which exist in the craters are suddenly voided, as happened in Ætna when floods issued from it which swept away rocks and quadrupeds with ease. Showers of ashes also fall, and often surprise wild animals—destroy, bury and preserve them. In this way it is that we find the skeletons of so many quadrupeds entombed in the ancient ashes—conglomerates as they are called—the rocks being formed of the pebbles carried down by these floods.

But before I speak farther of the quadrupeds of that period, all of which are now extinct, let me describe more minutely the operations of the first period—the first gradual filling up of the lakes and the formation of the Lacustrine strata; then we will speak of the origin of the volcanic mass and of the animals buried in it. Let us first ask how these ancient lakes were filled up. We find around the borders, and under the other strata, beds of pebbles which have been derived from the rounding of fragments torn from rocks in the neighborhood; and there is this remarkable circumstance connected with it, that no geologist has ever detected a single pebble of volcanic origin in these conglomerates. Every one knows that if a river flows from a country abounding in particular rocks, it will tear off and carry along portions of them, discharging them near the shores of the sea. The fine mud is carried out to a greater distance. Now there are vast piles of volcanic rocks, some soft and others hard and capable of being rounded; though they are sometimes a hundred feet thick, not one is found in the old gravel beds of the Lacustrine formation. The inference is obvious—that *not one volcanic eruption had occurred*, any more than upon the borders of Lake Superior, which is a country without volcanic rocks. This negative fact alone proves that in the first period the region was tranquil and no volcanic eruptions had occurred.

The gravel beds at the bottom of the lake soon became fine sand and passed into fine marl:—some sand was carried to a greater distance as you may now see falling clouds of it at the mouths of rivers settling to the bottom and being carried out. Marl which has a leaf-like appearance is often produced by the small shells of an insect called *Cypris*—a crustacean—or between an insect and a crustacean—which is very like a bivalve, such as fresh water muscles, with this difference, that it molts its integuments, while the others do not.—Accordingly myriads of these shells fall to the bottom, and for hundreds of square miles you may find that the strata have plates and leaves as micaceous sand-stone to divide; and this is produced entirely by the cases of that small species of animals. Many other shells show that this is a fresh water and not a marine formation, and this may show how gradual was the process that went on, as does also another kind of rock called *Indusial Limestone*—which consists of thousands of cases of animals which have been imbedded by the waters that flowed into the lakes. This is in the upper part of the marl, and we see it breaking out in the side of the hill at Clermont, when it occurs in round nodules. Every one of these consists of cases of insects encased by limestone. This insect, which is called *Phrygarea*, when it is in the *larva* state, and exists in the water in the form of a caterpillar, covers its case with shells to give it a proper weight; it often takes a hundred shells at once; as we see in the American Lakes they take small stones for the same purpose. They often seize upon these shells without the least ceremony, even when the fish are alive within them, and walk about in this way. It seems that they swam about in these lakes when they fell one after another encased in carbonate of lime, until you may now find the whole mass leagues in extent.—This may give some notion of the time required, and the gradual process necessary to produce beds 1,200 feet thick. You may often find the seed vessels of plants petrified in these beds. In several lakes of New-York—in Seneca Lake for instance, the whole bottom is covered by a green plant called *Chara* and *Gyrogonite* in such numbers that without other indications these alone would tell us of the origin of the formation.

It was formerly a matter of great difficulty with Mr. SCROPE and other naturalists to explain how Indusial Limestone is often found over wide areas; it was easy to see how it might exist near the shore, but not so easy to understand how it should be found at a great distance out; for the borders of these ancient lakes, with all their bays, can yet be traced as accurately as if they now existed. How should these Indusial Limestones be found ten or twelve miles from shore? A few years since, while in Denmark, I believe I found an explanation. In company with Dr. BECK, an eminent naturalist of Copenhagen, I saw in a lake 20 or 30 miles in diameter a large band of rushes or reeds floating on the water; they had been torn up and floated out miles from the shore. And on every one of them was an immense number of these *Phrygarea*, wafted out with them; and I found that twice every year a crop of these rushes of different kinds is produced, covored by different kinds of Phrygarea, and carried out by storms to the middle of the lake. Thus was removed the difficulty which before had existed with relation to this part of Auvergne.

The transition from the Lacustrine period to the Volcanic is not abrupt. Changes rarely occur so suddenly as are represented by geologists. None such have taken place in Auvergne. Though the two periods are very distinct, yet the volcano began its eruption before the lakes were drained. Showers of ashes fell into the lakes so that volcanic *tuffs* are often found to alternate with the marl containing limestone which is the upper part of the formation. Here and there may also be found *dikes* or threads of basalt. These facts show that there were few outbreaks of this igneous matter before the lakes were drained, when great rivers were still carrying down mud to the lakes. But the lakes soon disappeared and then commenced the excavation of the valleys.

Of this excavation of the valley there is a beautiful example along the valley of the Ceos. When about twenty miles beyond the termination of the stream of lava which came down from mount Dor and filled the valley—we find *breccias* in which are contained the bones of animals. A large part of this formation contains beds of pumice stone, which is sometimes found floating on the sea; it is produced by the trachyte that is thrown up, the gases expanding within it producing the pores. There is no pumice in the basaltic formation nor in the upper part of Mt. Dor; but in the older portions you may see thousands of them showing how gradually the mountain was formed just as were the Lacustrine formations.

In a general view of these subjects you may despair of understanding them; but when we examine the minute parts and sub-divisions—when you see the animal remains preserved in the strata and see in the volcanic rocks how one shower of ashes has fallen above another, you will begin to have hope of comprehending the successive steps by which these geological monuments have been built up. We see how the mountain was formed by the greater filling up of volcanic matter at that point than elsewhere; after that we see how the valley was again hollowed out, and then came the flood from Mount Dor bringing along the rhinoceros and other animals of the second period. Again was this cut out, leaving bones enough to determine its character; and lastly the river had its channel occupied by the most modern lava stream. About 40 different species of quadrupeds have existed there—of all sizes from that of the water rat to the great Mastodon.

In the eruption of Coseguina, in Nicaragua, Central America, on the 18th of January, 1835, only seven years ago, there was a fall of ashes which reached several hundred miles, and some fell at Chiapa, 1,200 miles distant. But for 25 miles the beds were ten feet thick. Birds, cattle and wild animals were scorched to death in great numbers and buried in these ashes; fish were smothered in the rivers; birds fell from the air, and the destruction extended over a vast region of country. There is evident reason to believe that a similar eruption occurred during the formation of this ancient mountain, and that the creatures which lived there were buried in the fall of red-hot, melted matter from the air. Between the two eruptions there was probably a long interval, and the animals had time to recover their numbers. There have been intervals of seventeen centuries in the history of active volcanoes. In the island of Ischia is an instance: and in the history of Vesuvius there was an interval of five centuries. We have a description of Vesuvius in 1631; it was then covered with wood; its crater was five miles in circumference, and over its edge, after descending a short distance, was a beautiful copse wood; grassy plains spread out below, cattle were grazing upon them, and a pleasant lake added charms to the scene. The peasants who lived about them had begun to look upon the stories of fiery floods having poured out of it as fables of the olden time. All was peace and security. But there came an earthquake, and in an instant all their forests and grassy plains and their animals were hurled into the air with the ashes and flame; then arose as from a caldron a fiery flood that filled the whole gulf, flowed down in seven rivers and took a direction directly over where Herculaneum had been destroyed sixteen centuries before by a similar flood of molten lava: and thus one town was buried beneath the other. After the heated gases have found relief, burst forth and been discharged, it appears that the duct or channel gets sealed up—the lava cools and consolidates, and it then requires no little force to burst it open again and cause a new discharge. Thus there is a long interval of rest until the gases again accumulate and have sufficient force to make for themselves a passage.

Thus much for the Lacustrine period, and now a few words respecting the more modern volcano as a type of the class which are the result of only one, two or three eruptions, and are often formed on the peaks of Vesuvius and Ætna a the hight of from 500 to 700 feet in a few months. There is a considerable crater at the top, covered with beautiful chesnut trees. Getting at the top of the crater you look down into a deep funnel. One circumstance of interest in regard to this is its loose, incoherent nature. There can have been no violent rush of water, of sufficient force to carry away animals, else much of this loose matter would have been carried away. Every thing about it looked so fresh that one would say it could have been formed but a short time ago, and yet we find no mention in history of any eruption in this part of France; and when we go down the valley and examine the lava stream which we know to be its own, we open our eyes to the prodigious antiquity of this most modern volcano. By reason of its loose structure, as is also the case with Ætna all the rain that falls upon it is imbibed at once, and no streams can be formed down its sides.

Following these valleys along you see at last the old river bed as it was in the olden time when there was no lake and the river flowed on uninterruptedly. It has a bed of pebbles—formed by rounding the fragments of basaltic trachytic rocks from the higher country and from the cappings of the hills. At a still higher point we find no volcanic pebbles, because there were no volcanoes;

that then must have been once the lower portion of the country in order to be a water course, as we know it was.

Cæsar encamped his army but about ten miles from Clermont, and yet it does not appear that he was aware of any eruption having taken place in that vicinity, else he would have alluded to it in his Commentaries. And Apollonarius certainly would have recorded it had any such eruption taken place within his historical knowledge, as he resided in this vicinity and wrote a very minute account of its history; but it does not appear that he had the least idea of the origin of the lake. So that his silence is conclusive as to the high antiquity of the occurrence of even these modern events.

You have from these observations some idea of the great succession of events contemplated by Geology. If you ask me why all these hills and valleys may not have been formed at once in the origin of things?—why they may not all have been called into existence at the same time as the nucleus of the planet itself?—I may answer, that even the brief skeleton of facts I have given will be sufficient to show that this could not have been the case; that these hills and valleys were no made at the same instant, but that they were the work of different causes, acting at different times—some being produced by the action of water, and others by fire; that they were produced at different periods of time by secondary causes, appointed by the Author of Nature to govern the successive changes in the inanimate and possibly in the animate creation, which he had in his wisdom employed in producing the successive changes of which the records are found in the very structure of the globe.

LECTURE II.

In the course of my last Lecture, while endeavoring to describe the geological phenomena of a region about the centre of France in Auvergne, I had occasion to introduce you to several classes of strata—the *granitic*, the *volcanic* and certain *aqueous* strata, constituting three of the grand divisions of the rocks of which the Earth's crust is made up. Let me remark that by the Earth's *crust* technically we mean that part of the exterior of our planet which is accessible to human observation; and the whole of this may be said to be made up of these three kinds of rock.

The *granitic* rocks are crystalline and contain no organic remains which have been mentioned as characterising the sedimentary or aqueous strata. They are crystalline masses and the true granite is unstratified. It has no pebbles nor any of those *tuffs* or porous rocks which are found in the volcanic class.

The *volcanic* rocks may also be said to be void of organic remains except those portions which I described as containing beds of sand and ashes showered down from the air or which fell into lakes; or except those *Breccias* and conglomerates which I described as having flowed down the flanks of some volcano as at Mount Dor, in which quadrupeds and other animals have been buried and their skeletons found so as to determine what animals inhabited that country when the overwhelming catastrophe occurred.

The *aqueous* strata, or those which were formed in lakes and seas, are the next division. I shall only allude to these briefly by saying that they are known to be of fresh water formation from the fresh water shells, &c. which are found imbedded in them. These fresh water strata compose but a small portion of the strata of the Earth's crust: just as lakes now are of small extent in proportion to the seas on the Earth's surface, so were formerly the estuaries and lakes of small area compared to the ocean: and we find these sedimentary strata containing Lacustrine or fresh water remains much less extensive than the marine strata. We find the strata of marine origin, containing sea shells and corals, at all distances from the present shore of the ocean, and at all hights above the level of the sea. This fact alone would render the results of geological investigation extremely interesting. We find the marine strata often far in the interior: and among the Alps there are met, 10,000 or 11,000 feet above the level of the sea, rocks containing unequivocal remains of creatures that once lived in the ocean. I have myself gathered limestones containing marine shells far above the hight of perpetual snow in the Bernese Alps and at Mount Carmel, the highest point of the Pyrenees And still more recently there have been found in the Himmelayn Mountains 16,000 feet above the level of the sea, similar organic remains; and this not only in the mountains, but limestones containing these fossils are continually found through the whole table land of Thibet; so that this vast platform of Asia is made up of rocks formed—not at the most ancient geological period—gradually beneath the ocean, and which have since risen up to higher regions. I speak as if we had already proved that this process is carried on by the upheaval of the land and not by the subsidence of the sea. In my next Lecture I will endeavor to convince you by distinct evidence of the mighty changes that have taken place, that this was the result of a rising up of the land, and not of a sinking down of the sea. Speaking in the language of that theory, these mountain masses, which now appear at hights of one, two and even three miles above the level of the sea, were formerly beneath the ocean, and were raised up during the first era of animals and plants, and not all at the same period.

Now the sedimentary or marine strata which enter thus largely into the masses of the Earth are divided into various groups, which we refer to distinct periods. They form a chronological series of volcanic action—a history of the Earth; and when we trace this series down from the most ancient to the most modern, it is not till we arrive at the latest of the great series that we come to these groups that environ the section of France which I have already described. Grand as was this series of events, it is not till we arrive at the latest of the larger groups that we come down to this Epoch. I shall not at the present meeting attempt to sketch the history of the different formations, but continue to describe most particularly this strata and those which are cotemporaneous with it—those containing the remains already alluded to, or those of a posterior date. Now the oldest of the series of which I spoke last, is the fundamental granite and the fresh water formations are imposed upon it. In order to classify the different depositions which belong to this more modern period of the Earth's history it is indispensable to attend to the organic remains, and particularly to the shells contained in it;—shells are more useful in this science than any other indications, and have been appropriately called the *medals*, by aid of which nature has recorded the events of the most ancient history of the globe. They are found in such abundance in the fresh water and marine strata of all ages that by comparing and contrasting them we may build up a chronological series, and find characters clearly to distinguish the different periods. In the fresh water formation in the neighborhood of Paris are found twelve hundred species of these shells—carefully distinguished from each other; as is well known to Conchologists only some thirty of these species are known now to exist any where upon the globe. We are acquainted with about 10,000 species of shells; and of those only 30 resemble any of the 1200 found in this strata.—You may ask how we know that these rocks were formed in the lakes in the province of Auvergne, at the same time that the others were formed in the sea on the site of Paris. The manner in which we make out this cotemporaneousness is briefly this: Rivers carry down shells to the sea; the shells of the American Lakes, for example, are carried from Lake Erie and the other lakes by the river St. Lawrence into the marine gulf of St. Lawrence. The Tiber carries down the fresh water shells of Italy to the Mediterranean, and deposits them in the Delta. So of the Adige and the Po; and if we examine the strata in the Delta we find that they are filled with fresh water shells and contain also marine shells. So in the neighborhood of Paris—shells of the Lacustrine deposit are mixed with marine shells. Quadrupeds, too, are carried down by rivers and deposited with the 10 or 1100 species of marine shells of which we were speaking; and by this means we first know that these quadrupeds lived, and these shells inhabited the lakes when the sea was inhabited by these testacea. In Vicenza, Italy, we find certain marine strata, and in Paris these alternate with volcanic formations, and thus we make out the cotemporaneousness—the Synchronism—of a certain volcanic formation, and a certain marine or Lacustrine strata.

It is necessary to have some technical names for these periods, otherwise it will be impossible for you to follow me when I allude to them. By a few terms we may express in a word what it would be tedious otherwise to express. By the *Eocene* period, then, I mean the oldest as when this fresh water strata of Auvergne and other districts contains the same shells of alternating strata. It takes its name from ηως—the ***dawn*** and καινος, ***recent*** because the fossiliferous strata of this period contain but few species that are now living, which may indicate the dawn of the existing species of testaceous fauna. The next period I call *Miocene*, from *μειον less*, and *καινος*, *recent*; because it contains a *minority* of recent species—a much greater number than the Eocene, but still a minority. The next period is the *Pliocene*, from *πλειον* more, and *καινος*, recent; because it contains a *plurality* of the existing species. That is, out of 100 species of shells found in the Eocene, one or two only will be of those now living. When the land had been raised by volcanoes—in the Miocene period, about one fifth or twenty out of the 100 may be identified with existing species. And if we come down to the more modern or Pliocene period more than one half the shells are identifiable—and sometimes 90 out of the hundred.

When the volcano which formed Mount Dor in a period distinguished as recent, was filling the lakes in that region, by volcanic eruptions lakes and seas in other parts of Europe were filling up and that at no great distance. If you travel from this mountain to the Loire near Tours you may find great numbers of marine depositions—strata rich in shells; and you may find, too, some of the very quadrupeds buried by the ashes and scoriae and breccias which floated down into the sea, and were buried near the shore in marine depositions; enabling us thus to prove that those strata were formed in the same period, and that the basin of the Loire was formed in the same Zoological period as this Mountain. So also in Bavaria are many Lacustrine deposites, and on the Rhine you may find the same quadrupeds associated with fresh water shells. Thus extending your observations from one part of Europe to another, you can prove that in the second period there were volcanoes making marine deposites. This is it on the borders of the Loire between Tours and Mount Dor; and four-fifths of the shells found there are of now extinct species—while the other fifth are still living. This period is called Miocene—as containing a minority of shells of existing species.

I might remark that these formations are found all through the United States. In my tour to the South I found in Virginia formations belonging to the first or Eocene period. [The whole group is called Tertiary, to distinguish it from the Secondary formation. A friend lately suggested to me that he could never remember the order of the different periods—Eocene, Miocene and Pliocene, until he observed that it was the natural order of their initials E. M. and P. in the alphabet. These little helps to memory are often of considerable value.] At Richmond, Va., at Wilmington, N. C. and for 40 miles on the Santee river and between Augusta and Savannah I found Eocene strata, containing shells of a species identical with those found in the Paris basin; the same shells are found all along your coast as on ours. You have on the James river beautifully developed the marine Miocene strata—and this fact has before been pointed out by RODGERS and other American Geologists, whose observations I am only confirming and perhaps adding something of my own. You see there the strata containing marine species in nearly the same proportion as those on the Loire.

But I must not spend time upon these matters lest I pass over the main object of the present lecture. If you had examined a portion of this Country when the Lacustrine and Eocene strata were largely developed, and should then go some 20 or 30 miles from Mount Dor and explore the valley of that part of France, when on all the hill sides you found nothing but fresh water formations, you might say that between the white marls that contain these shells and the other period there was nothing intervening except a thin stratum of vegetable soil; and that therefore (a mode of reason often followed by geologists,) there must have been a sudden transition from that state of the globe under which the *Palæotheria* lived, and when shells peopled the lakes—crocodiles, turtles, &c.—to the present; that there must have been a sudden annihilation—a sweeping away of existing races, and an introduction of those that now inhabit it. But when you pass to Mount Dor and observe the manner in which the volcanic strata overlie the fresh water, you will see how vast a period must have intervened between the present and the Eocene—giving time for another race of quadrupeds—the mastodon, hippopotamus, hyena, and other animals to supplant the more ancient. But you may ask might not *this* at least have been the last formation? Examine the great sheets of lava which are there. Then follow on and find where suddenly they are cut off and again resumed—a vast bed of pumice, and trachyte and basalt corresponding to a similar one on the other side of the valley. Consider that instead of this being the last in the series that there has been an excavation of the great valley, and a throwing up of the Puy de Tartaret and the flowing out of a stream of lava for 30 miles, and then a subsequent erosion of the ravines by the lava. By this time, if you are a philosopher, you will have acquired more caution, and will not hastily assert that the Miocene period was the last; you will say rather that on extending the sphere of your researches you were obliged to abandon your first opinions, and so if you still farther enlarge the field of observation to other parts of Europe, you would see that there was another strata between the Miocene and our own—and such is the case.

When you have entered Italy and followed the Appenines from the Po to Calabria you find a low range of hills called by Brocchi, an Italian Geologist, the Sub-Appenines, consisting of strata of a date posterior to the Miocene. These we call the Pliocene—which are divided into the Older and Newer Pliocene. I shall not dwell upon the first but allude to the Newer Pliocene, or more modern part of the group. In the South-Eastern part of Sicily we have an example of marine formations of the Newer Pliocene. There are rocks of marine origin in which you would at first say that all the shells were the same as those that now people the waters of the Mediterranean; and yet when you come to a more careful examination you will find that one-tenth are of a species never seen in that sea. These rocks are sometimes 2000 feet thick, and it would be easy, if I had time to describe them minutely, to show that they had been accumulated in the same slow and gradual manner as the fresh water strata of Auvergne were elaborated by the deposition of one layer after another, with this difference, that in the former the organic remains are marine, and in the latter they are those of lakes, and therefore a fresh water species. Another difference is that volcanic rocks are distributed nearly through the whole thickness of the formation in the South of Sicily. Near Syracuse also you may see a strata 2000 feet thick, alternately of volcanic and marine origin; at the bottom is a bed several hundred feet thick of volcanic ashes, then a bed of limestone, on which rests the great sheet of lava. In one of these strata at Vinconza an observer found a bed of oysters 20 feet thick. There had been time for this oyster bed to accumulate—for *Serpulae* and other parasitic animals to attach to them until the bed grew 20 feet thick; and then a stream of lava rolled over it. These facts show how gradually these strata were formed. Another remarkable circumstance is that these rocks rise 2000 and in Castrogiovanni, in Sicily, 3000 feet above the level of the sea. These have all been formed since the newer series of strata were deposited. Volcanic matter often rises in the sea, overflows the bottom and forms a temporary island, as Graham's island was formed five years ago. The waves soon destroy it, spreading the volcanic matter over the bottom of the ocean. All this takes place before there is any upheaval. Here, too, we have proofs of what an extended series of groups in the chronological table is to be formed subsequent to the Miocene period—the date of that volcano, before you think you have come to the end of the series of modern events—those which are considered as belonging to modern history.

My principal object in the present lecture is to convince you how far from the end of the series these rocks were formed, although they have a respectable claim to antiquity. When we examine Ætna, and the strata on which it rests, we shall see another period, called the Post-Pliocene period, as being subsequent to the Pliocene. In this all the shells are of the existing species. Its formation has been sufficiently protracted to admit the elaboration of this vast series of volcanic movements. The locality which I will select this evening is Mount Ætna—for that volcano rests on strata in which all the shells and corals appear to be identical with those now found in the neighboring seas.

The hight of Ætna is nearly 11,000 feet. It was well described by the ancients. It is divided into three distinct zones, called the *fertile*, the *woody*, and the *desert* regions. The lowest, the fertile, is a most beautiful territory, embracing the delightful country around the skirts of the mountain. It is well cultivated, covered with groves, olives, wines, corn, lemon and other fruit trees, and is densely inhabited. When you pass above this, (and its extent may be judged when I say that the base of the mountain is ninety miles in circumference,) you come to the woody region, a thick forest of chestnut, oak, and pine trees growing upon lavas of different dates: and as you go higher you occasionally find groves of oak and beech.—This region is rendered extremely beautiful by the great number of minor cones, or small volcanoes like the Puy de Tartaret, which have broken out at different periods on one side of the mountain. Some of these are four or five hundred feet high, and one of them, Monte Minardo, is seven thousand feet high. There are few objects in Nature more beautiful than this multitude of minor cones that have broken out and covered the trees of this woody region. This zone is two, five and in some places six miles wider and when at its upper limits you are about five thousand feet above the level of the sea. From the upper confines of this forest region, in 1828, I took a sketch of the scene above us. We climbed up upon the eastern side.

But from that point we have still six thousand feet elevation between the highest point and the foreground of this picture. The mountain is generally symmetrical, in the form of a flat cone, broken down upon the eastern side by a deep chasm called the *Val del Bove*, as may be seen in this figure.

[Only that part of the drawing presented by Mr. Lyell, which is necessary to show the Val del Bove, is here copied. The following are all the explanations necessary:
a—highest cone of Ætna.
b—Montagnuola.
c—head of Val del Bove.
f and *g*—lateral cones.
At *e*, the extremity of the ravine, is a little village called Zaffarana, at the lower border of the woody region. *Rep.*]

After entering upon tho woody region, and riseing about one thousand feet from the base, you reach a great precipico two or three thousand feet high; then comes a plain covered deeply with snow, and lastly the cone, eleven thousand feet above the lovel of the sea, from which steam or aqueous vapor is constantly emitted. When these views were taken, which was in October, thero was less snow upon the mountain than at any other period of the year. One eruption from the summit occurs for every two of the cones on the flanks.—When one of these happens the melted lava pours out over the snows, which are suddenly melted, and rush down the mountain, producing sometimes floods which sweep down the flanks and across the valleys. Except when floods thus occur, there is a singular absence of running water on the flanks of the mountain. The silence which pervades on this account is quite remarkable; for no torrents dash from the rocks, nor is there any movement of running water as in most mountainous countries. Not a rill runs down tho sides. All the rain that falls from the heavens, and all the water from the melting snow is instantly absorbed by the porous lava.

There are numerous vertical dikes which traverse the mountain and sometimes extend for more than a thousand feet in a perpendicular. They consist of liquid matter emitted by fissures, which as it rises is consolidated, mixed with tuffs and scoriæ, and thus becoming harder than the cliffs around, resists decomposition and stands out in bold relief, while the rocks around are wasted away by tho rapid freezing and thawing to which this region is exposed. There was an opportunity during the eruption of 1669 of observing the manner in which theso dikes are produced. Tho mountain was rent asunder by fissures radiating from the centre—though some of them were parallel. These emitted a vivid light, showing the incandescent lava at a great depth below. The lava flows sometimes nine or ten miles down the split mountain, and when it is cooled and crystalized it forms one of theso vertical dikes. Similar dikes are formed in Madeira, where basalt has been traversed by volcanic rocks.

It is supposed that as often as Mount Ætna is rent open, thero may bo a slight upheaval of the whole mass—an uplifting bodily of the whole mountain: and if we suppose that this has happened from the earliest periods, it may explain the great difficulty which has puzzled some geologists in endeavoring to explain why the moro ancient part of the mountain has not been covered by posterior eruptions. It has been objected, that if the whole mountain was formed (as I believe it was) by successive eruptions, that the ancient parts of the volcano ought to have been buriod long ago by the more modern eruptions. I ought perhaps to have remarked, that there is a general dip of the beds in all directions, which there are two ways of endeavoring to explain. One attributes it to sheets of lava flowing to a certain point; and the other to an upheaval in the centre, tilting the beds in all directions. Both these may be in some degree true. I will now endeavor to show why tho most ancient parts of the mountain would not bo covered by the overflowing lava.

We know that there has been an upheaval of tho whole mass of Ætna at no very remote period; becauso the mountain rests on a marine stratum which contains shells identical with those now living in the Mediterranean. A force which could carry up this marine strata which skirts the sides of the mountain must have been able to carry up the whole mountain; and if the lavas did not cover, at each successive eruption, more and moro of this marine strata, we should be able to trace it to a greater hight up tho mountain. As it is, we find it about 1000 feet above tho level. If tho ancient part of tho mountain has been thrown up in this way, we readily find the explanation of the phenomena we aro seeking. First, let mo state that all geologists admit that the formations of alternate lava and scoriæ of which the mass of Ætna is constituted, is of supra-marino origin—

that it is formed above the water; for it contains no marine shells—no beds of tuff—no stratified mass—no fossils; but has every indication of being a volcano found in the open air. At first, the volcano may have been of moderate hight—accumulating one bed upon another until it reached a height of 4 or 5000 feet. Then as it grew higher an eruption would take place, as it does now, chiefly on the flanks. I told you that an eruption generally occurs on the summit for every two on the sides: that is the proportion that has been observed during the historical period. The higher the mountain becomes, the greater, evidently, is the hydrostatic pressure of the column of lava that rises up: the higher the chimneys the greater the pressure of the lava rising within them upon the flanks. In this way the lava might continue to rise until at last, if it became more than two miles high, the pressure would have become so enormous as to burst through the flank of the mountain. Every geologist will admit that in a volcano such an outbreak may take place. At first, before this the accumulation went on by eruptions from the summit; but these eruptions being afterward performed on the flanks about the woody region, the older part of the volcano was not buried.

Before I go farther, there is one point of great interest which I will notice: Ætna is of all volcanoes that of which we have the most ancient records, and to a knowledge of which history and tradition carry us the farthest back. There is a tradition mentioned by Diodorus Siculus, that an eruption happened before the Trojan war, which compelled the Sicani to desert their district. Thucydides tells us that in the sixth year before the Peloponnesian war, or in 435 B. C., an eruption occurred which was the third that had taken place there since the colonization of Sicily by the Greeks. (a) The second of these three eruptions was the one mentioned in that beautiful ode of Pindar, which is worth referring to because it is the description by a poet which corresponds precisely with the appearance of the volcano twenty centuries afterward when Catania was destroyed in 1669. Part of the city had been overflowed during the eruption, alluded to by Pindar, as having occurred in the year 475 B. C. In that passage Pindar speaks of "*the snowy Ætna, the pillar of Heaven—the nurse of everlasting frost, in whose deep caverns lie concealed the fountains of unapproachable fire—a stream of eddying smoke by day—a bright and ruddy flame by night: and burning rocks rolled down with loud uproar into the* [illegible]." (b)

We have sti[illegible] 'stream of eddying smoke' by day produced [illegible]n eruption. It had the same appearance wh[illegible] saw it in 1828, and also when Mr. Scropo saw [illegible] stream nine months after it began to flow in 1819. He says that it was then moving on at the rate of one yard in an hour: during the day it constantly emitted a dense vapor: for aqueous vapor enters minutely into this lava, though no chemist has yet fully explained it. As often as the stream cracks, it emits several gases, but chiefly steam, which boiling up brings the lava to the surface, and causes it to overflow the crater just as steam in a kettle carries up the water, and causes it to spill over. So this steam and all the gases become entangled with the red hot lava, causing it to discharge large quantities of aqueous vapor during the whole process of conglomeration. By night we saw the same cracks emitting a glowing heat, and the whole stream makes out the 'bright and ruddy flame.'

It is a singular circumstance, in regard to the theory of flowing lava, that, instead of being level, as you would naturally expect of a liquid, there are hillocks of considerable hight along its surface, in consequence of the uneven ground over which it flows. Another peculiarity of these streams is the fact of their becoming hard and solid while in motion. Instead of thinning out, as would be natural, at the edges, the upper surface becomes cool, and the sides likewise, and both grow hard; so that the edges are often rocky walls, inclined at angles of from 30 to 40 degrees. It is thus a flood of red hot lava flowing along a solid tube. Thus, when they come to a rise of ground, the streams rise as water does in a pipe—as has been the case in the Val del Bove. When the stream comes to a hill, it goes up the slant in a tube of its own making, and thus, too, it goes up the sides of solid walls. In 1669, when Catania was threatened with destruction by the approaching stream, a respectable citizen of the town, desiring to secure the city, took a troop of

(a) Thucydides, Book III., Sec. 116.

(b) This passage may be found in the 1st Pythian Ode of Pindar, beginning

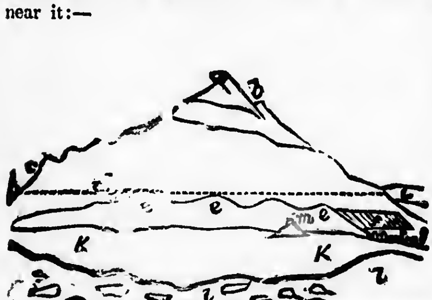
Χρυσεα φορμιγξ Απολλω-
νος και ιοπλακαμων
Συνδικον Μοισᾶν κτεανον, κ. τ. λ.

The description of Ætna, the whole of which is extremely beautiful, commences with the concluding lines of Dec. V.

κιων
Δ 'ουρανια συνεχει
Νιφοεσσ Αιτνα, πανετες
Χιονος οξειαφ τιθηνα,

and is continued through the seven succeeding verses. [Rep.

some fifty men, who, clothed with skins to protect them from the heat, and armed with iron crows and pick-axes, began to quarry the solid walls and let out the lava. They opened it at the village of Bolpasso, and the stream immediately issued forth, and took the direction of Paterno. But the inhabitants of that town, being alarmed for the safety of their own village, took up arms and prevented farther operations. The torrent, therefore, moved on to Catania, and the inhabitants of that city, being terrified for their safety, turned out and threw up a rampart of stones, hewn from the lava, sixty feet high. On went the burning torrent, and when it arrived at the wall, it continued to accumulate upon itself until it topped the wall, curled over, and fell in a fiery cascade upon the town; it passed on to the Mediterranean, which it entered with a loud explosion. This corresponds precisely with the description of Pindar. The Prince of Biscari afterwards, at great expense, made a quarrying out of the lava, so as to show the manner of its falling over; and you may now see the upright wall, with the stream of lava curling over the top—appearing like a petrified cascade of lava, and remaining visible to this day. This drawing will give you some idea of the view of Ætna, and the situation of various localities near it:—



a—highest cone.
b—Montagnuola.
e—marine formation—rarely found above the dotted line h i.
f—escarpment of volcanic tuff, &c. N. W. of Catania.
g—town of Catania.
k—plain of Catania.
l—limestone platform of the newer Pliocene, from which the view is supposed to be taken.
m—La Motta di Catania.

From these facts you may get some idea of the slow manner in which the lava current goes on, at the rate of a yard an hour for days, months, and sometimes for years.

It is very generally conceded that the origin of the chasm on the side of the cone—the Val del Bove—was in the subsidence of the ground for some 3000 feet. We have an example at no very remote period when the Dutch possessed the Island of Java, of a similar sinking down in the volcano Papandayang—but a little before the commencement of the nineteenth century. A space of ground some fifteen miles long and six or seven wide gave way during an earthquake, and buried forty villages; and one part of the volcano fell in after another, until Papandayang lost 4000 of its hight. The mass engulphed was larger than we need suppose was swallowed in order to produce the Val del Bove on the East side of Ætna. There are two mountains mentioned by Pliny, and since his time the chasm between them has been nearly filled by the deluges of lava.

The composition of all the lavas of Ætna, from the oldest to the most modern, is singularly homogeneous. That of the modern eruptions of 1811 and 1819, when analyzed was found to consist of the dark mineral augite, and of a kind of feldspa, called Labradorite. It has large quantities of iron, some of which is titaniferous. The most ancient lavas of which thousands of sheets are found, consist of nearly the same materials. At those points where we can see farthest into the internal structure of the Mountain, we find that it is constituted of successive beds of lava and scoriae—with large quantities of augite and feldspar, which have a granitic structure. As we go farther down, we find masses of rock, which are still more granitiferous: they are not divided into strata, nor do they agree with the volcanic rocks; we thus reach the *Plutonic* rocks, and I must endeavor to make you familiar with the technical term. Volcanic rocks are frequently porous, because they are found near the surface, and the discharge of their cases causes pores in them, as in the *slag* of iron furnaces. When they exist in a strata of considerable depth, the pores diminish and the rocks become stronger, and begin to crystalize, until we reach the bottom, when they have no pores. Crystalization has taken place under a pressure, and they have slowly cooled. The Plutonic rocks consist of certain porphyries, and have silex and alumine, but never scoria or volcanic sand or pebbles, nor are any signs of these found near the surface. As, therefore, Volcanoes had been thus named, because Vulcan had his forge under Ætna, so it was natural that these rocks should be called Plutonic, as being found in the realm of Pluto, where flowed the Phlegethon—river of fire—and the Lethe rolled its watery labyrinth, which may be mythical of the Lethean influence exerted by these rocks—for we find that when these granitic masses come in contact with a fossiliferous strâta, they destroy every trace of organic remains. If we suppose all the different strata to come in contact with these, we shall find that we can trace the passage from those of the most fossiliferous state to that when fossils are rare, at last come to a pure crystal rock, such as is sought by the Sculptor.—The Carrara marble is an example of this kind.—Formerly this was called a primitive rock—one of the oldest. Now it is known not to be of high antiquity, but to have been converted from fossiliferous rock by contact with granite, which has deprived it of all its corals. Its nodules of flint have been fused, and occasionally will be found crystals of augite, against which the Sculptor sometimes breaks the edge of his chisel. I give this as an illustration with which you are all acquainted; it is only one of a thousand I might mention. Thus you see that rocks which are fossiliferous, when far from Plutonic rocks, may become non-fossiliferous when placed for ages in their vicinity.

It was formerly a great puzzle for chemists to account for the manner in which heat pervaded the rocks, because they are bad conductors. But they should recollect that in the interior of the Earth we have to deal not only with masses of melted matter, but with steam. Volcanoes, besides mineral matter, discharge various gases—but nine-tenths of their matter is water. This steam, before it found vent, mingled intimately with the pores of the lava, and forced the sides to disengage. Any rock, no matter how solid and compact, when put in contact with an immense reservoir of this would become porous and spongy, under so enormous a pressure. This may be seen at Corinth, in the Lipari Islands, in Greece, and other places. This hypothesis must not be combated, then, by objections founded upon the results of subjecting rocks to the heat of our furnaces; for they exist under altogether different conditions in the interior of the Earth.

I may state, that, as these remarks relate to the most difficult theories of geology, it is not to be expected that you should at once follow them. As I omitted it at the last lecture, I will say a few words of the origin of granite rocks. The true unstratified granite is generally believed to be of igneous origin, formed by that part of the volcanic phenomenon which is far below where the eruption takes place. In Mount Dor, they are believed to be below the Miocene, and in Ætna, below the Post Pliocone; and so of all antecedent periods.

It is impossible, though we know more of the history of Ætna than of any other volcano, to form even an approximate estimate of the number of years required for the accumulation of such a mass of volcanic matter. There is no reason to suppose that the ancient eruptions were more violent than the modern. The sheets of lava separated by beds of scoriæ and breccia, in the ancient part of the volcano, do not appear to be of any greater thickness than those of the modern. There is one method of attempting the computation of the more recent part of the mountain—to consider the minor cones which adorn its flank. Of these there are eighty of the first magnitude. We cannot, from what we know of these, suppose that more than one-fourth of them were produced since the earliest periods mentioned by Diodorus Siculus and Thucydides. There may have been more activity, or less violent convulsions; but if we suppose that, in 12,000 years all these eighty cones were produced; and if we strip them all off, we shall still have the great colossal mass of Ætna remaining behind. It would still be one of of the loftiest mountains in Sicily. It is evident, at all events, that, between the formation of the latest period of the Puy de Tartaret and the oldest of Ætna, the whole of the older and newer Pliocene periods must have intervened.

In my next lecture I will endeavor to explain, from the remains of the temple of Serapis, some of the proofs of the upheaval of the earth.

LECTURE III.

UPHEAVAL AND SUBSIDENCE OF THE EARTH.

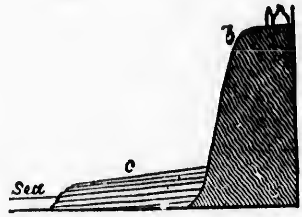
Ladies and Gentlemen: I have had occasion, in both my previous Lectures, to allude to the fact that various marine fossils—tho fossil remains of animals that once lived in the ocean—have been found entombed in the rocks of various districts; not that we find these remains of marine creatures strewed over the surface of the Earth merely, as if the Sea had once overflowed the land; but we find them imbedded in the midst of mountains, at all depths below the surface, and entering into the composition of the mountain masses themselves, making up their very materials, sometimes for two or three miles thick, all having been gradually elaborated under the water; thus furnishing the most indisputable proof that what is now dry land was once for ages under tho water and formed the bed of the sea. Here the geologist finds himself reduced to the alternative of supposing either that the ocean was once higher than it now is, and that it has been lowered; or that tho land, the solid land itself, has been raised up. The earlier geologists preferred tho notion of a sinking, a general sinking, of the sea; for the ocean cannot be lowered in one place without a general subsidence throughout its whole extent. But when the structure of the Earth came to be more attentively studied and more thoroughly examined, geologists gradually came round to the opposite opinion, namely, that the land had been elevated; and this opinion was embraced for several reasons, but principally because it would account for all the observed phenomena, explain all the periods of stratification—those in which the strata are disturbed and fractured as well as those in which they are horizontal. For if they were all upon a level, then the going down of the sea might explain their appearance; but as we find them curved, bent and fractured, the other theory is the only one which will explain both appearances.

Another reason for embracing the hypothesis of an upheaval of the Earth is this—that we find in the crust of the Earth fresh water formations—(you are now familiar with this term)—beds formed in lakes and estuaries, lying beneath the deposites which are evidently of marino origin. For example, in some parts of Europe you find the white chalk—a marine, calcareous matter, produced beneath the sea mainly by the decomposition of shells; beneath that you find another stratum, evidently of fresh water origin. Now to explain how a marine stratum 1,500 feet thick could have been thus deposited upon a fresh water formation, by the theory of the rising and the lowering of the ocean, you would have to make the ocean first retreat, in order that thero might bo dry land; then rise again to deposite the mass of corals and shells which are found; then retire and again go down to explain the present dry land which now exists in that part of the Earth where this calcareous matter is found. You would have a vast number of successive retirals upon that hypothesis; and the ocean must riso several miles and stand there for ages to form the marine rocks of the Himmelaya and other mountain chains.

But besides that this theory of the movement of the land explains all these geological phonomena, we have the experience of history, which teaches that the solid land, through extended districts, does sink down in some places and riso slowly in others; whereas there is no instance on record of a general lowering of the whole ocean—there has been no general sinking of the sea throughout the world. I think I shall be able to show in this and the next lecture, that there has been, and is now going on, a magnificent example of this, sometimes of a sudden and at others of a gradual and insensible rising and sinking of the earth. I will here mention one example in Sweden, because originally I disputed the accuracy of the statement, until I visited the locality and satisfied myself of its truth. I found that the Northern part of Scandinavia, of Sweden and Norway, was rising five or six feet in a century, as is ascertained by facts that have been observed for several hundred years. As you go south to Gefle you find that the rising has diminished to three feet, and at Stockholm to only two or three inches in the hundred years, while still farther south there was no motion at all. It is thus as if the whole land were a lever, which is stationary at one point, rising more and more as you go toward the end. In Greenland it is certain that since the early Danes colonized the island, built churches there and settled the country, there has been a gradual sinking down of the whole coast for several hundred miles; the churches in some places have been submerged, and the greater part of the lower stories and the pavements are now wholly under water. These movements of the earth are sometimes accompanied by volcanic eruptions, though not in Greenland and Sweden, but in South America they are. In Chili, for example, in 1835, that part of the coast near Conception was raised some nine feet, and remained permanently at that hight. The bed of the sea was raised, as were the island of Santa Maria and a great part of the neighboring coast; at the same moment the volcano of Osarno, in the Andes, burst forth and lava was seen to flow from its crater. A submarine volcano also burst forth 400 miles west of Osarno at Bacalao, and the island of Juan Fernandez was also violently shaken. These facts show the vast extent of the subterranean volcanic activity accompanying the movement of the land. The land has relapsed in some degree, though not to its former position. In some places it maintains its upheaval.

But you may see a more remarkable illustration of this upward and downward movement in the immediate neighborhood of Naples: and I mention it because evidence drawn partly from antiquarian researches and partly belonging to geological proof, comes home more easily and more convincingly to the minds of those not accustomed to purely geological evidences. In my next lecture when I come to speak of the coral reefs—I think I say not too much when I say that I shall show that these vast areas of the Earth's surface—extending some 8000 miles from East to West, and 3000 or 4000 from North to South—are now undergoing in some sections a slow upheaval, and in others an equally gradual subsidence. To-day I shall confine my attention to a small space in the neighborhood of Naples, where the changes may be traced for the last 1800 years.

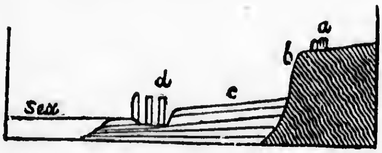
If you first look at a map of the country near Naples, you see extending into the Bay of Naples, south of Vesuvius, the Sorentine Promontory, off which is the celebrated Island di Capri. Pompeii you will see at the south side of Vesuvius, and Naples at the northwest. At the northwest extremity of the beautiful Bay of Naples you see the small bay of Baiæ, to which I would call your particular attention. Now movements have taken place, which have caused a sinking and then a re-elevation in the Bay of Baiæ of twenty-five feet—and yet have not affected the neighborhood of Naples, which is only twelve miles distant. This view of the Bay [exhibited] was taken by Sir William Hamilton, from the south side of the Bay at Puzzuoli. On the plain between the sea and the dark cliff, represented below is the town of Puzzuoli.



a. Antiquities on the hill S. E. of Puzzuoli.
b. Ancient Cliff—now inland.
c. Terrace composed of ancient submarine deposits.

This inland cliff is eighty feet in hight. When I examined it in 1828, I found that it consisted of indurated volcanic tuff, containing some marine remains and the platform or terrace *(a.)* between the cliff and sea, contained evidences of having been formed under water. A wall had been built to protect the rich and valuable land of the terrace which slopes from the base of the cliff to the sea. But fortunately for me, a storm had swept away a part of this rampart and laid open a section so that I was enabled to examine the alternate beds of pumice and lapilli and volcanic matter, with strata abounding in various marine shells, such as cockles and the *Mytilus edulis* or eatable muscle. In one of these strata I found squares of a rich colored mosaic pavement and various sculptured ornaments. My friend Mr. Babbage found at a great hight barnacles and other shells attached to the face of the cliff. The appearance is as if the sea had beaten against the base and thus undermined the cliff.

When we pass round the promontory to Puzzuoli and come in sight of the Bay of Baiæ we see what is called Caligula's Mole, a long line of arches and piers extending from the end of the town into the water. On the last of these arches but one there were found, ten feet above the sea level, great numbers of flustra and other marine zoophytes attached to the building, which must once have been submerged ten feet lower than it now is and then raised to its present hight. On the sixth pier the same thing may be noticed. Breislak observes that as these arches now spring under water, and as it is certain that originally they were built so as to spring out of the water, though it is proved that the mole has been uplifted ten feet above its lowest level, still it has not yet been restored to its original position. If you stand on one of the arches and look toward the land you see another inland cliff similar to, but not so high as, the other. Between the cliff and the sea is a low terrace called La Starza, leading to the inference that the same movement which produced the other cliff, also extended to the Northwest and produced this with its plain and caused the cliff to become inland. Upon this plain is the temple of Jupiter Serapis. The cliff and plain are represented in this drawing:



a. Cicero's Academia.
b. Ancient Cliff—now inland.
c. Terrace of Submarine deposits.
d. Temple of Jupiter Serapis.

I will now mention the manner in which this temple of Jupiter Serapis was discovered. In traveling along this terrace—which corresponds so exactly to that on the other side—some antiquaries in 1749, examining all the localities, saw concealed among some copse wood, the upper part of three columns—several feet above the ground.—They were struck with the circumstance, and determined to remove the copse. They did so, and began to dig down to see how far the columns extended. They dug down, accordingly, ten, twenty and thirty feet, and still found these great shafts: at forty feet they found nobottom; but at forty-six feet they came to the pedestals, on which these columns stood. They were buried at this enormous depth, and when they had completed their digging, they found a large pavement, seventy feet in diameter, level at the base of the columns.—Having found this, and still continuing to clear away, they discovered a large quadrangular building, the roof of which had been supported by forty-six of these magnificent columns, of which half were granite, and the rest marble—the marble in each case being a single block, whole from top to bottom. Now, in attempting to account for this, you might at first, perhaps, suppose that the temple was buried like Pompeii, which was overwhelmed by a shower of mud and ashes—and was, after more than fifteen centuries, disentombed, and an immense amphitheatre dug out and exposed to view. You might think that this temple of Jupiter Serapis was thus buried, being in the region of the Volcano of Solfatara, of which an eruption occurred in 1149. But we find that some of the beds, which have been dug through, contain marine shells, and fragments of works like these I mentioned as having been found in the terrace on the other side of Puzzuoli, and the situation of the temple is that represented in the drawing (d.)—In endeavoring, too, to account for the burial of this temple by the rising and sinking of the sea, you have first to suppose, as the temple was built above ground, that the sea first went down—for the presence of marine remains in the lowest strata, shows this: then that it was carried up again.—But it is evident that in reality the temple was built above the water—that it went down and was buried in the sea, and that again it was raised.—You may think all this very difficult to believe; but there are still greater wonders to account for, and which can be satisfactorily explained, when you come to examine the building.

The marble columns have been examined. For the first twelve feet from the bottom they are smooth and uninjured—just as they were originally in the interior of the temple. (I shall not stop to discuss the opposite opinions as to the use to which this temple was put. It is generally called the temple of Jupiter Serapis—from the ornaments found in it. Several hot baths are found also—and hot springs which still flow out from the ruin.) Above this point is a zone of about nine feet perforated by *Lythodomi*, a kind of marine bivalve which has the power of perforating rocks. The upper part of the column is smooth having only marks of its exposure to the weather.

These animals which have thus perforated the columns are a species called *Mytilus Lythophagus*—or stone-eating moluscas. A diver at the Bay of Genoa once told me that some years before he had thrown to the bottom a piece of black marble to be bored by these animals: I prevailed upon him to go out in a boat, dive down to the bottom and bring up the marble. It was filled with these shells—about the length of your finger, buried in the solid rock. It has long been difficult to conceive how these tender shells and the still more tender animals that inhabit them, should be able to thus eat holes in the solid rock. It was supposed by some that they had the power of turning around as on an axis, and that thus the shells scraped out the holes like a file. But so tender are the shells that this seems impossible. If we suppose the animals to secrete an acid capable of eating away carbonate of lime, of which the marble is composed, the question will occur. why should not the acid eat up the *shells*, which are made of the same substance? But we may well suppose that a feeble acid may act on the rock and not eat into the shell which contains the living animal—especially when we recollect that the shell is covered by an Epidermis or skin, upon which the acid will not act. It is probable that as they grow large—for the hole they make at first is small—they are enabled to eat away the calcareous matter by discharging the acid they secrete. They have drilled into the columns pear-shaped, cylindrical cavities, which it must have required a considerable time to excavate. Their numbers are so great, and they have so eaten into the columns as to diminish their diameter: and we find that some of the cavities which the *Lithodomi* have deserted have been occupied by a specie of bivalve. The appearance of the columns is indicated by the following figure.

Total hight from bottom of Plinth 41. 1¼.

When first these phenomena were observed in the last century, it caused a great variety of opinion: and this was not confined to scientific men, but even the poet GOETHE wrote an essay to explain how the salt water of the sea (in which alone the lithodomi exist) might have been barred out—enclosed in a barrier so as to account for this appearance. As there are no tides in the Mediterranean, how is the water to be carried up not only to the hight of twelve, but of nineteen feet? I do not say that if there were tides they would explain it; because the Lithodomi cannot live six hours out of water like bivalves, which take water into their shells: they must be always submerged.

But some geologists have asserted that there must have been a general change in the level of the sea; that it must have stood nineteen feet above its subsequent level. But it may be replied that there are a thousand proofs to be drawn from the history of all other parts of the Mediterranean, that no such change has ever taken place. It is certain that the temple existed in the third century: for, in the atrium inscriptions have been found recording the reparations made by the Emperor Marcus Aurelius, and the additional ornaments given to it by another Emperor, Septimius Severus. We know then that it was used as a place of worship—or for whatever purpose it was built—down to the third century: and nothing is more certain than that between the third and the middle of the last century there has been no general rise of the Mediterranean.

Nevertheless, in spite of this difficulty, many maintained that the sea had gone down. So unwilling were they to entertain what they called the paradox of attaching constancy to the sea and mobility to the land. But after a time their opposition gave way. In 1828, the year when I had an opportunity of examining the place, some excavations were made through the pavement, and at the depth of six feet below it the antiquarians came upon another pavement more rich and costly than this. This suggested the idea that there had been a sinking down previous to the changes we have noticed. The building being near the sea, as it gave way it was necessary to construct a new pavement six feet above the other; and then upon this the whole building was erected.

The next discovery was made by Niccolini, who was employed in 1807 to make drawings of the temples; he was in the habit of remaining there all day and yet never saw the pavement overflowed by the sea. Sixteen years after, he had occasion to go back to the temple, and to his surprise he found many parts of the marble pavement where he had stood in 1807 dry, covered at high tide by water. (I said there was no tide in the Mediterranean; and it is usually considered a tideless sea. Still there is a slight rise and fall of a few inches in the Bay of Baiæ.) This led Niccolini to make a series of experiments with the hydrometer; and he found t... the ground in 1840 had been sinking at the rate of about three fourths of an inch annually, so that in 1840, it would be two feet two inches lower than in 1800. When I was there it was always covered with water. When you know that the land is thus positively going down every year at a gradual rate you will be less skeptical in relation to the subsidence of the earth's surface. Thus we have not only to carry down the temple far enough to account for the nineteen feet we had before, but now we are obliged to add six feet farther for it to sink; we have now twenty-five feet of subsidence to account for.

Now, the question was, was this sinking gradual and successive, as it has been since 1800, or was it sudden? And to this we have a most satisfactory answer. In 1828 Mr. Babbage, the celebrated mathematician, and another of my friends, Mr. Head, carefully examined the temple and found the clearest evidence that the whole was gradually going down; and Mr. Babbage had the kindness to lend me the yet unpublished results of this examination. We find the columns eaten at the ends and upon the sides, and they wished to show how the columns must have stood to allow this. They found first, the whole column incrusted near the bottom by a black deposite two feet thick, containing *Serpulæ* and marine animals.—We may suppose that the temple had then begun to sink so that the sea should have covered the base of the columns where this incrustation was deposited. The top of the deposition represented the water level. Then came a shower of ashes, covering the column for six or seven feet, from an eruption of the neighboring volcano of Solfatara, probably, though there are many other volcanic cones in that vicinity. Now this may have shut out the sea, and the water flowing into pools and ponds of the uneven surface may have caused the fresh water formations, as there are no serpulæ or marine animals to be found there. Then may have occurred another shower of ashes, perhaps from the eruption of 1149, when was a considerable earthquake, which may have thrown down the other columns which perhaps stood till that time. Suppose the marble ones, (for the granite are untouched,) then to have rested on the uneven surface of the layer produced by the second shower: the sea flowing in might have carried the lithodomi thither, and thus the columns might have been eaten on all sides and at both ends.

All these geological phenomena relate to the periods of the successive goings down of the temple. No less than 27 pillars have been carefully examined and measured inch by inch and their original position carefully made out. In the year 1488 it appears that the rising began to take place, when the great earthquake occurred which destroyed Puzzuoli and formed those inland cliffs. We have a document, a charter of Ferdinand and Isabella of Spain, then sovereigns of Naples, granting to the University of Puzzuoli the piece of land near the town of Naples 'where the sea is drying up,' (*che va seccando il mare;*) and this was followed a few years after by another charter dated in 1511, granting to the University, *solum desiccatum*, the *ground that is dried up* from the sea. So at this time there is evidence that the gradual retreating of the sea had begun. In 1530, nineteen years after, we have still the testimony of an Italian writer Soffredo that though the sea had dried up still it washed the base of the inland cliff and swept across La Starza so that he tells us people might have fished from the ruins. We are now led nearly to the epoch of the formation of Monte Nuevo—the new mountain produced by an eruption in 1538 only eight years after Soffredo wrote. And there is ample evidence in the documents collected by Sir William Hamilton that the whole upheaval of the land took place about that time. I shall refer to some account of that memorable event when a mountain 450 feet high was produced in a few nights. This mountain stands partly on the site of the Lucrine lake and partly on the site of a little village in the vicinity called Tripergola. Sir William Hamilton has found two letters describing the eruption which formed the mountain and I shall read from them some interesting passages. One is from Falconi in which he says:

"It is now two years since there have been frequent earthquakes at Puzzuoli, Naples and the neighboring sections. On the day and in the night before the eruption of Monte Nuovo above twenty shocks, great and small, were felt. The eruption began on the 29th Sept. 1538. It was on a Sunday about one o'clock in the night, when flames of fire were seen between the hot baths and Tripergola. In a short time the fire increased to such a degree that it burst open the earth in this place, and threw up so great a quantity of ashes and pumice stones mixed with water, as covered the whole country. The next morning the poor inhabitants of Puzzuoli quitted their habitations in terror, covered with the muddy and black shower which continued the whole day in that country—flying from death, but with death painted in their countenances. Some with their children in their arms; some with sacks full of their goods; others leading an ass loaded with their frightened families toward Naples; others carrying quantities of birds of various sorts, that had fallen dead at the beginning of the eruption; others, again, *with fish which they had found* (mark this,) and which were to be met in plenty on the shore, *the sea having left them dry for a considerable time.*"

This is the description of the eruption of the volcano that formed Monte Nuovo, by Falconi; there is another by Pietro Giacomo di Toledo, in which he says:—

"It is now two years since Campagna has been afflicted with earthquakes—the country about Puzzuoli more than other parts. On the 27th and 28th of September last, the earthquakes did not cease day or night; the town of Puzzuoli, that plain between Lake Avernus, the Monte Barbaro and the sea was *raised a little* [a remarkable expression which he would not have used if it had been merely a shower of ashes which raised it, as sometimes happens] and many cracks were made in it, from some of which issued water: at the same time the sea adjoining the plain *dried up for about two hundred paces*, so that the fish were left on the land a prey to the inhabitants of Puzzuoli. At last on the 29th, about 2 o'clock in the night, the earth opened near the Lucrine lake and discovered a horrid mouth, from which ever vomited furiously smoke, fire, stones and mud composed of ashes, making at the time of its opening a noise like the loudest thunder. The stones which followed were by the flames converted to pumice, and some of these were *larger than an ox.* The stones were sent a high as a cross-bow can carry," and so he goes on to describe the shower of mud that built up a solid mountain which has a crater at the top as deep as the mountain is high. Toledo then proceeds to say that the eruption lasted two nights and two days—(the mountain was produced in two nights,) and that many persons were knocked down by the stones, and killed.

It appears to me evident, not that the sea had retired before the eruption, but that, when the tremendous explosion took place, the plain was suddenly raised, and there was then a drying up of the sea some time after; but a vast deal of rising must have taken place during those convulsions, as we know the red hot lava to produce that liquid fiery matter that was thrown up must have melted near the surface, so that the stream, instead of flowing over the crater, should escape through the yielding beds below—between which it might flow latitudinally until it became high enough to pierce through, just as it is easier to thrust a knife between two leaves of a book than through them.

But I have too many facts to explain to you relative to these superficial changes having been caused by an upward and downward movement of the Earth, to enter this evening upon the various speculations respecting these matters. You perceive that we have carried the temple down twenty-five feet gradually, and that it has shot up nearly the whole distance, though not entirely, at one eruption.

Not far from the Temple of Serapis are the ruins of two temples, one of the Nymphs and the other of Neptune. The columns of the former stand erect in five feet water. The temple was doubtless submerged, and if there should ever be an upheaval of the bottom of the bay, this temple would probably be exhumed as was the other. As to the difficulty that arises from the columns not having fallen down like the others, it should be recollected that they went down slowly, only three-fourths of an inch in a year, and that before the great earthquake of 1149 occurred, they were buried twelve feet deep in incrustation or in ashes; being made of one block, they would be quite likely to remain erect.

One fact I forgot to mention: that these columns are a little out of a perpendicular—inclining slightly toward the sea. Originally they must have been perpendicular; therefore the movement must have been greater toward the land; and this, too, may explain why the temples of Neptune and the Nymphs are lower down and are not yet raised. An antiquarian, named Capocci, has proved conclusively that while these movements occurred at Puzzuoli, no changes have taken place at Naples, so that we have an oscillation of twenty-five feet up and down, while at twelve miles distance every thing is stationary: an important fact in the explanation of a great variety of geological phenomena, some of which I alluded to in my other lectures.

When you examine the new mountain you find no indication that it is more modern in its origin than the others in its neighborhood. Indeed, as the same country is under cultivation, for the most part the vines are lifeless for much of the year, and the olives are of a pale green. But Mt. Nuovo is covered with evergreens, myrtles, olives, and arbutus:—it is the most verdant spot in all that region: showing apparently that it is less modern than the barren hills in its neighborhood. Nothing can be more striking than the whole landscape—every part of the picture is in such perfect harmony with the rest, that you would not suppose different dates belonged to the different mountains.—Yet I have found at a hight of 2,600 feet marine shells, identical in species with those which now live, buried in the strata of ancient, submarine tuff. The whole country, which is so modern, either consists of this volcanic matter which has been thrown up since it emerged from the sea, or of strata in which you find shells and zoophytes identical with those that now live; and yet when the early Greek colony first took possession of it 2,500 years ago, the appearance of the valleys and hills was much the same as you find it now. You can scarcely avoid being surprised at the prodigious antiquity, relatively to the historical period, even of the modern strata containing the same shells which I have spoken of in my last two lectures, when alluding to the antiquity of the great mass of Ætna, while all its vast sheets of lava and scoriæ rest on marine formations as modern as the Bay of Baiæ. These species of plants and animals which inhabit the hills of that country are more ancient than the country itself.

Now you may say that this is an apparent paradox: yet you will easily comprehend it if you attend to such a mountain as Nuevo, which since 1538 has been colonized by all the wild plants and animals of its neighborhood. So Ætna has been covered with vegetation older than the mountain itself; not only were these species of animals and plants alive before the country rose from the sea, but during that whole period when the vast thick strata of hills first began to be elaborated at the bottom of the ocean. So we may affirm that the *Fauna* and the *Flora* of this region are of a higher antiquity than the country itself. Were I to attempt to give you an idea of this period of time—the most modern subdivision of which, this tertiary and its succeeding periods, I have thus far considered—if I were to compare it to any thing of which we have a conception, I would say that this period, of which I have spoken thus far, may be compared to such distances as exist within our solar system—between the different planetary bodies.

Now when astronomers endeavor to measure the distances of the solar system, they tell us that the earth is one hundred millions of miles from the sun; because they find that when six months have gone around, the earth is in the opposite side of her orbit, which is two hundred millions of miles in diameter. They calculate, therefore, by the angles subtended, with the diameter of her orbit as the base, that a distance of one hundred millions of miles is between the earth and the sun. Then Jupiter is five times as far away; Saturn ten times, and so of the others.

Yet when they attempt to estimate the greater space which separates our Solar System from the nearest star, which again is probably the centre of a System as magnificent as ours, they are baffled in the endeavor, and can only find a distance which shall be the *minimum*—nor till lately have they arrived at any accurate calculation concerning it. But it seems, by observations on the parallax, a Prussian astronomer, Bessel, has measured the distance of one star in the constellation *Cygni*.—The angle subtended by the diameter of the Earth's orbit at that star is found to be *one-third* of a second, and what distance does this third of a second give you? Take the diameter of the Earth's orbit for a unit, and then 700,000 of these units, will express the distance of one of those stars in Cygni from our Earth, and perhaps that star is the nearest, and separated from the others which we see by a distance equally vast.

Perhaps, should we compare time and space, this would be the kind of distance which should contain the myriads of organic remains of species distinct from the species immediately antecedent and following. The minor subdivisions of which I have spoken would be compared to the space of our own solar system: the others, with the grander stellar distances.

Now it is a favorite speculation of astronomers, that all these worlds, separated so widely, may be inhabited; but this is mere conjecture—a probable conjecture, if you like, but still incapable of demonstration. But the geologist proceeds differently. He has indisputable proofs, that there have existed on this planet a succession of inhabitants, and distinct races of animals and plants. And though he does not measure the limits of time so accurately, and with such geometric precision, as the astronomer, still, by the vast series of events—by the methodical phenomena of the earth—he finds established, by purely physical phenomena and proofs, the declaration of Revelation, that in the first time Man had no existence; that man had a beginning, and that other races existed anterior to him. Man had a beginning; and therefore the present state of the organic world has not gone on from eternity, as the ancient philosophers pretended; and we have been able to prove, that beings lived, called by the Creator into existence, on this planet—to display the beautiful and perfect harmony of the Universe—to show that all is modeled on one plan; that different as are the various genera that have lived, they all belong to the same family. Geology shows that all things are the works of one Intelligence—one Mind—all links of one chain;

that the Earth must have been admirably fitted for successive states which were to endure for ages. Thus do we learn to admire the variety and beauty of design displayed when we find traces and signs of the same design, the same unity of plan, the same harmony of wisdom through so vast a series as has been established by the Infinite and Eternal Creative power.

LECTURE IV.

CORAL REEFS.

I have already said that in the structure of the crust of the Earth we have a great variety of groups in which the distinct strata may be expressed, if we group them largely—if we take wide and comprehensive divisions—by the different numbers and colors, as from one to eight in this figure [exhibited]; and that the different sets of strata—formations as they are called—are arranged one above the other in the order in which they are formed. Not that they are invariably all to be met in one place, for it is not often that we find more than one, or two, or three, of these strata in any particular district: but if these different sets are present, we shall find them arranged in the order of relative position in which they are represented—each corresponding to the different period of the Earth's history at which it was formed. So that they may be regarded as a great chronological table—as so many volumes of History in which the strata are the different pages; and upon them are written the names and characters of the plants and animals which lived and flourished at this period, with many other indications of climate, habits, &c. in the periods when the different tribes flourished.—Now if we examine in succession these rocks we find that a great number of those of calcareous formation, or limestones, are composed in great part of *corals and shells;* for example, if we take the Chalk formation of Europe—represented in the figure as No. 2—we find a large portion of it to be a white calcareous rock made up of corals and shells almost entirely decomposed. I have myself seen in the island of Seeland, fifty miles from Copenhagen, at Faxoe, this very chalk formation pass into a mass of corals in which more than a hundred species of zoophytes and shells are found. Between the zoophytes is found chalky matter—like the ordinary chalk. This formation extends for more than a thousand miles in one direction, and eight hundred in the other—not continuously, but in large patches, which preserve much the same character. In this country too, as in New Jersey, are found rocks of the same age, not with the white rocks of the same kind, but at different intervals down we find in the rock, corals and shells made up of an aggregate of extinct species, but in great part of genera, the same as now live in tropical seas. And this is regarded as one proof that formerly the climate was much warmer than since; as it is only in warm climates that these stone building zoophites increase and abound. There are zoophytes of the same class in all regions of the globe: but those which form large masses of stone (which, when the animal dies becomes what we may term hard rock,) are found at present only in warm regions of the globe.

Now, I might trace the different formations in which they occur, and point out the limestones in which they abound. In what is called the Jurassique or Oolite formation, these corals are found through England, France and Germany, at different hights with great intervals of clay—in some cases six or seven hundred feet thick. The corals are found above the other except when they have been destroyed by the depositions of clay, for they can live only in pure water. It is clear that where these take place and in the intervals between the different layers of coralline formation there had been a sinking of the floor of the sea, since it is found that these zoophytes cannot build in the deep and dark parts of the ocean,—that they will not thrive in a depth of more than 120 feet below the surface: and therefore we find a mass of this coralline limestone with 1000 feet of clay above and then another layer of coral, and then 1500 feet thick of this cretaceous rock; it is evident that these were formed not at a depth of several miles but near the surace: and that they then sank down to allow the accumulations above.

If we come to the carboniferous or coal formation, (which I shall describe more particularly in my next lecture,) we find beds of coal separated by vast thicknesses of other strata, which can only be explained by supposing that there has been a sinking of the surface of the land. Below the coal are found the most ancient fossiliferous rocks, which have an antiquity far higher than the thick limestone, for the corals grow on spots which are now found covered in great part with extinct genera, or those which are only found in tropical seas, where coral reefs abound. In New-York, in particular, there are large developements of this formation, as I shall show when I come to speak of the district around Niagara, when I shall show the lights from which we are to suppose the bed of the sea has sunk, and the era when these marine plants and animals abounded. Now if we find, on examination of existing coral reefs that have limestone in their structure, similar in their character over a vast extent of the globe, that there is now in progress a considerable going down of the bed of the sea; we shall then feel more confidence in the appearances and facts on which depend some of the most interesting problems respecting the origin of the materials of the Earth's crust.

I shall now proceed to give some account of the Coral Reefs, and of the manner in which they grow in the sea. I have been favored by Mr. Charles Darwin, who is about to publish a most excellent work on Coral Reefs, with this map—which will first be published in his book—drawn up after a personal examination of the region represented, and a most extensive reading of works upon the subject. On it are depicted all the spots known at present where Corals now grow. These portions [represented by the blue color] mark those places where there is reason to believe the bed of the sea is going down, as slowly, perhaps, as the floor of the Temple of Jupiter Serapis, described in my last lecture. By the red are marked the spaces where Corals have been raised at various elevations above the level of the sea.

You will be able to see at a glance the vast extent of the region where corals abound. You will see, too, that it is chiefly within twenty degrees North and South of the Equator—in the warmest parts of the ocean. Sometimes it reaches beyond the twentieth degree but rarely so far as thirty. Its greatest deviation is in the Bermuda Islands, which have a latitude of thirty-two degrees—which is the farthest point from the Equator where corals are yet known: and this is evidently connected with the course of the Gulf Stream which warms the ocean and raises the temperature beyond what naturally belongs to that zone. You see by this map that in the Indian Ocean in particular and in the great Pacific and South Seas is a prodigious growth of corals. And it is a very remarkable circumstance that almost all the islands in that part of the sea—all that are colored blue—consist of strips of coral of an annular form—more or less perfectly circular—and sometimes oval. And these strips have *lagoons* in the centre—small lakes of salt water. On one side of this narrow strip is an unfathomable ocean at but a short distance from the edge of the ridge of coral. It was formerly supposed that these coral reefs were built up from the bottom of the unfathomable ocean; but now since we know that these *lithophytes*, as they are called, cannot exist at a depth of more than 120 feet—the limit assigned by Darwin (and some other considerable naturalists think that the limit is still more narrow,) we infer, as a fact of Natural History, that these were not built up from the bottom of the ocean. And this is perfectly in accordance with the fact that in thousands of cases no soundings are to be found at enormous depths—only a fourth or half a mile from the outer part of these narrow rims of coral. One of these circular islands is represented in this picture, which was taken from an original drawing colored on the spot by Lieut. Smythe who accompanied Capt. Beechey in his voyage to the Pacific. It may be proper to say that the view is represented as having been taken from a higher point than the top of the mast from which it was actually taken, so that more of the inner part of the island can be seen than in the other case. The island is three or four miles in diameter, of crescent shape, and you see a narrow rim of coral covered with tufts of cocoa, and bread fruit and other trees. On the windward side the reef is higher than on the other; and on the leeward side is an opening of thirty or forty feet—so that ships can enter and lie in safety in the lagoon. This opening, most fortunately, is just on that side where it is most needed; for there, during terrible storms and tempests, vessels may enter into the tranquil lagoon, where the water is shallow, compared with the ocean without, and where, in consequence of its shallow depth, it is of a most beautiful green color. Many of you who have sailed across the Atlantic must have observed that, along the Banks of Newfoundland, where the water is comparatively shallow, it is of a deep green; and in those latitudes where there is white coral at the bottom and a burning tropical Sun over head, the vivid green of the sea water is described as most beautiful by those who have visited these islands. Down through its green depths, they tell us, you may see great herds of fish browsing upon the coral branches—for some species have strong, bony jaws by which they easily crush the coral, shell and all: you see them feeding upon the zoophytes as the herds of buffaloes feed on the herbs and trees of your wide prairies. And even the prairie itself in spring time is not enameled with more beautiful colors or with a greater variety of flowers and plants than are those beautiful beds of coral, according to the descriptions of EHRENBERG and others who describe these lakes as like beds of tulips—so beautiful and variegated are their colors when seen through the still waters beneath that tropical sun.

I may here mention a fact of considerable geological interest relating to one of these fish, called *Sparus*. When their bodies are opened and their intestines examined, they are found to be filled with a very dry chalk—a soft, calcareous powder, which proves to be almost indistinguishable from soft, pulverulent chalk. I have myself seen some brought from the Bermudas by Lieut. NELSON, which so nearly resembled European chalk that we were obliged to use great care lest the labels should get changed, and we should mistake it for the chalk with which we were comparing it.

The animals which form these reefs—for the whole is a rim not half a mile, and generally but three or four hundred yards wide, covered often by shells of *Echini*, or sea urchins and other shell fish—cannot build one inch above the level of the sea. They cannot allow themselves to be left bare at low tide; so that when the reef is so high that it remains almost dry, the corals leave off building. The heat of the sun then often causes the mass to crack, and the force of the waves tears off large branches of the coral, which are thrown up upon the reef, thus raising it above the reach of the usual tide. After this the white, calcareous sand thrown upon it by the wind lies undisturbed; and upon it are lodged the seeds of the coconut and other plants, which grow up, until at length the little island is overshadowed with luxuriant vegetation. Then come stray birds and build their nests there; insects float thither on wood which has drifted thousands and thousands of miles, and at length the island becomes inhabited. Here is a specimen of the *Meandrina* coral—[exhibited;] it is a small shell of a young animal; and you can conceive, when such is the size of this baby-coral, how vast must be the size of a number of zoophytes of different genera—as the *Madrepora, Astrea, Porites*, (of which I here show you a section,) the *Oculina*, and others, of which the remains are found in the older rocks, and which now abound in the tropical seas. These shells and zoophytes constitute the mass of the materials of these reefs. As to the nature of these animal plants, as they are called—and very properly, too, for they seem to form the intervening link between animal and vegetable organization—there is still great doubt. I shall only observe those called *Pollyps*, inhabiting this stony structure, have a number of *tentacula*, or feelers, and a great cup-shaped mouth, into which they force food seized by these tentacula, and which then closes, and they are able to digest their food. These assist in strengthening that part which is improperly called the root; for they are fixed at the lower point by a point which somewhat resembles a root, though, as it does not take in nourishment, as do the roots of vegetables, the analogy is not correct.

In the common red coral of the Mediterranean you see a solid internal skeleton, surrounded by a fleshy covering, which, in that case, is smooth; but when this, in which the animal resides, is taken off, you see a striated, fluted surface, to which attention must be paid in studying the fossils—since we have not the living animals. I shall not enter (as I have so much geological ground to go over,) upon a description of the different varieties of Pollyps. But you may ask whether they exist as separate, independent individuals—or whether the whole mass of coral is regarded as one and indivisible. The same kind of question may be raised with regard to trees:—whether each flower is a separate individual, or whether the whole is to be regarded as an aggregate. We may perhaps best consider them as an animal republic, in which all combine to build one habitation, while each preserves its individuality. The general opinion, both in regard to the plants, and zoophytes, is that each is a definite individual.—Although so beautiful when in the water, take one of these stone building corals out, and you see nothing but a brown slime when the animal is collapsed.

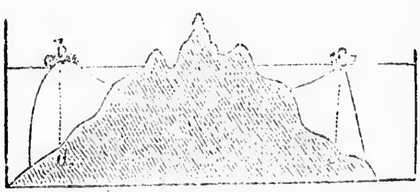
It is a remarkable circumstance, that, although these little islands are scattered about so far from each other in the wide ocean, upon every one capable of supporting them were found a few families when first discovered. We should regard this as mysterious if we did not learn from the Voyages of Cook, Koezebue, Flinders, and Lieut. Beechey, that canoes are frequently drifted 500 or

1500 miles—driven before the wind in one direction by the monsoon, until, hopeless of recovering their homes, they land upon some one of these islands—whero they find cocoa-nuts and bread fruit, and fresh water too. This is singular, for you would think that there would be but little chance of finding fresh water upon these small islands: but if you dig into the sand, there it is—so that vessels at sea are often ablo to relieve their thirst.

The beauty of these islands is described in glowing terms by most of those who have navigated those portions of the sea. Generally there is a constant white surf breaking over the outer margin, which is seen gradually to die away with the dark heaving waters of the ocean, which continue to boil and rage far beyond. Within, the water is green and tranquil; around it and outside the green line of blooming vegetation is a glittering beach of white sand. Beneath the water you may see fish and various kinds of Zoophytes. The very loneliness of these islands, moreover, gives them a romantic aspect. Sometimes they are seven hundred miles away from the nearest neighboring island, and more than a thousand from the continent, or even much farther. The structure of these islands, as well as their position in the unfathomable ocean, is remarkable. You find no part of them argillaceous or silicious; every portion is made up of an organic structure of which the tubes and stems are all you find. And what is still moro wonderful, these islands, which appear so weak and fragile in their nature—these mere barriers of coral are beaten upon incessantly by the swell of the great ocean, and yet are not annihilated. As DARWIN truly observes, if they were only rocks of common granite or quartz, they would inevitably yield to the prodigious force of these waves thus breaking over them.—But here is a greater power than any mere inorganic structure: in its nature far superior to the mechanical force of the waves: it is the power of life, of vitality; these zoophytes on the outer edge of the reef break the force of the waves by their yielding bodies; they bend like a willow before the storm, and thus conquer the power of the great restless ocean. Indeed that part of the reef against which the waves beat with most turbulence increases much the fastest; for these organic forces separate the atoms of carbonate of lime from the foaming breakers, and build them up into their symmetrical structure: myriads of these architects are thus at work, day and night—month after month.

But what causes the singular, ring-like shape of these islands and why are so many just on a leve with the sea and neither higher nor lower? These questions have been asked ever since the peculiar formation and mineral character of these islands were ascertained. It was at first imagined, and I once maintained the opinion, that they were the craters of sub-marine volcanoes. When it was discovered that Flinders was wrong in supposing that they could be built at a great depth, in the cold and dark regions of the ocean, up from the bottom, it was natural to suppose that they might have grown upon the tops of some submarine mountains. But what mountains would give this *shape* to the corals? Or was it indispensable that they should be built in this peculiar form? Now when EHRENBERG examined the corals of the Red Sea he found that some banks were square while others were ribbon-like strips with flat tops and without lagoons; and yet they were of the same genera as those which *had* lagoons, the same as the *atolls*, as they were named from those observed in the Maldive and Laccadive Islands, the term expressing an island with a rim of coral outside and a lagoon within. It was thus found that this annular shape is not essential; but that the corals may form in a different shape. It was therefore natural to suppose that this form depended on the outline of the submarine bottom, and that they were based on volcanic craters, thousands of which were known to exist in that part of the sea. These craters would give the cup-shaped center and the rim might be covered with corals by these zoophytes. In the South Shetland Islands and in Barren Island in the Bay of Bengal, are submarine volcanoes with craters in the center and a breach in the side so that you may sail within and see all around the walls of the crater. Now when submerged the corals might easily have been built upon them. In farther support of this theory it was observed that in Gambier's group of islands there were volcanic rocks with a lagoon in the center, just as modern volcanoes have sprung up in the Gulf of Santorin.

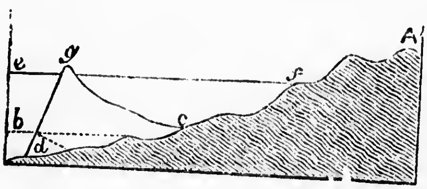
Notwithstanding all these arguments in favor of the theory of a volcanic origin, it was found necessary to abandon it entirely; because, though it would account for some of the facts, there were many others which it could not explain and which could be explained by another theory. It was perfectly satisfactory so far as the rim and lagoons were concerned and it also explained why the Ocean near by should be unfathomable, which at first seemed an argument in favor of the volcanic theory. Mr. DARWIN, after considering all the different facts I have related, observed that there were in some cases islands which had this same coralline ring, and yet were *not volcanic* but *granitic;* and yet the ring of coral surrounded a precisely similar lagoon.—How was this to be explained? Again, FLINDERS discovered a magnificent reef—on the North-East Coast of New Holland more than a thousand miles in length; and he sailed for more than three hundred and fifty miles and yet found no passage through that narrow reef. Instead of being circular or oval or in any such shape it was parallel to the Coast of New Holland. In the island of New Caledonia, which is granitic, there was also a long ridge of coral 400 miles long and prolonged at each end under the water beyond these limits: between the coral reef and the shore was what might be called a lagoon. Now we must have a theory which will explain these facts. Of these encircled islands, as DARWIN called them—islands with encircling reefs around them—Vancouver's is one and Otaheite is another. Here we have a coral reef with a lagoon inside. In the figure we have given a section of one of these encircled islands.



A represents the island in the centre; *c* and *b* are the points in the encircling reef upon which grow cocoa trees, &c., and inside, or between *c* and *b* and the sides of the island, is a shallow sea communicating with the ocean through occasional passages, similar to those met with in the lagoon. Now it was a rule laid down by DAMPIER and other navigators, that near high and bold coasts we shall have a deep sea; while along gently sloping coasts the sea will continue shallow for some distance from the shore. It was therefore surprising that when we had an island like that represented in the figure, going down at so steep an angle, instead of deep water, we find it shallow. Go two or three miles away, and still the water is shallow, and we have a coral bottom. But go beyond the reef, and down goes the line some thousand feet. It is obvious that the coral alone is the cause of the shallow water; and we must account by means of the coral for the fact that at a distance from the island, instead of several thousand feet of water, as we are entitled to expect, we come suddenly to a bottom. Now in what manner can these zoophytes, which cannot live at a greater depth than 120 feet below the water, be able to build up a reef two, three, four or more thousand feet high from the bottom? Because the belief of FLINDERS that these creatures could work in the deep, dark, cold ocean and build up their structures to the light and heat is proved not to be true; though he did not err as a geographer in his statements respecting these bold coasts.

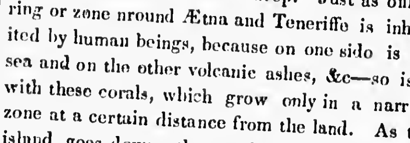
DARWIN here suggested a simple hypothesis which clears up the whole difficulty. Suppose the coral to begin to grow at *c* or *d*, in the figure above; and suppose these points at *that time* instead of being 1500 or 2000 feet deep, to be within 120 feet of the surface, the sea then standing at a different relative level from that which it occupies now. In short, the supposition of a *sinking down of the land* will explain it all. When the land began to sink the corals were building up, as is their nature, one generation forming on the skeleton of the other, just as peat grows until it reaches a thickness of a hundred or more feet; each successive generation plants itself on the remains of the former. So with corals: each mass forms a foundation on which a new one is built. As I have shown, or as Niccolini has shown, the rate of subsidence in the Bay of Baiæ is three-fourths of an inch a year. Now common Corals will grow up at that rate; and perhaps two inches a year would be a slow growth. Let me observe that we need only show that the greater part of them increase slowly; though passages of the Red Sea are known to have been filled up within a few years. This, however, may be easily explained, because the waves, &c., may have thrown up sand and thus filled these passages. But the common growth of the coral is slow. Indeed EHRENBERG thinks that some of the species, as the *Meandrina,* are as old as the most ancient trees of Europe, some of which are three or four thousand years old. DECANDOLLE has shown that some yews and other trees are two thousand years old, and some still more ancient. So Ehrenberg thinks that many of these corals in the Red Sea are several thousand years of age. But the vigor of their growth depends upon the warmth and carbonate of lime that reaches them.

Now we may suppose the land to be sinking down gradually as the corals are building up.—What is the consequence? Instead of sinking down with the land, the corals will grow up by building upon the former masses—just as one pavement of the Temple of Jupiter Serapis was built upon the other, which had sunk six feet below the level of the Mediterranean. And when these corals come to the surface and can rise no higher, the waves then throw up calcareous sand upon them and form a ridge as in the lagoons. But while the corals are thus rising up, the mass always gaining in hight above its original base and yet remaining in other respects in the same position, it is different with the land: every inch that it sinks is irrecoverably lost, and the distance becomes greater and greater from the island to the reef. If the island sinks down, it diminishes in size above the water; but the reef remains as it was, (though, from its slight inclination inwards, it may be a very little affected,) till at last the island peak disappears and is converted into a lagoon.—All the land disappears, and the island becomes a perfect *Attol;* and if the subsidence still goes on, the lagoon will acquire considerable depth. This theory also is as satisfactory in explaining the *barrier reef* as in accounting for encircled islands, lagoons or *attols*. Let us take the following diagram as representing a barrier reef on the coast of Australia:



Here the land, instead of going down abruptly to the sea, has a gentle slope. When the reef began to grow at *d*, suppose the land stood 1,000 feet higher than now; the level of the sea would then be *c c*. But as the bed went down, the reef would be raised 1,000 feet, or from *d* to *g*, and *e f* would represent the level of the sea. But as the distance *f g* is greater than *c d*, it is obvious that the higher up towards the surface the reef be built so much faster must the land be constantly retreating; and the rate at which this will go on is in proportion to the angle of descent. If at an angle of 30° one foot in vertical hight be lost, the change in distance will be about thirty feet. But in a gently sloping coast every foot in hight measures a vast number of yards; and the land will retreat at a greater rate. Thus the barrier reef is at a considerable distance from the coast—20, 30 and sometimes 70 miles off.

I ought here to say that corals will not grow too near the shore, in consequence of the sand and mud carried thither by streams and carried up by waves. It is only in clear, salt water that they live; fresh water poisons them. On the other hand, they will not grow too far away from land, because the sea is there too deep. Just as only a ring or zone around Ætna and Teneriffe is inhabited by human beings, because on one side is the sea and on the other volcanic ashes, &c—so is it with these corals, which grow only in a narrow zone at a certain distance from the land. As the island goes down, the corals build up, and we have nothing left but the lagoon. We have islands also in an intermediate state, as Tahiti and Gambier's group, most of which, however, are perfect *attols*. Nine-tenths of them have arrived at this state.



In this figure suppose A to represent an island 2000 feet high, and B a shoal in the sea, when *c c* is the sea level. Now if the coral grow on both islands as they sink gradually until it be 2000 feet thick, we shall have attols at the summits. If the top be washed, so that the corals will not grow, a ring will be formed, and grow up, and we shall have a lagoon; A will become an encircled island for ages, until it is submerged, and then the rising coral will form a lagoon. So that this *lagoon island really represents a sunken mountain.* This may be seen at Tahiti, in Gambier's group, and in the Dangerous Archipelago—an area of 4000 miles in one direction, and 600 in the other. From this you may infer what must have been the vast differences in level of so vast an area. Take any continent containing a thousand mountains, and how very great a difference will there be between the elevation of the different summits.—What a difference between the high and low!—And what an amount of subsidence must take place before they are all so sunk as that we shall see only the topmost, upon the same level! and yet to this are we led by the theory of subsidence; nor should we be terrified or frightened out of any sound theory by contemplating the vastness of the results to which it leads.

I may as well mention that this theory of subsidence was not invented for the purpose of explaining these phenomena. Long before DARWIN had made his examinations of these coral islands, in 1835, I published my opinion upon this point, that the sinking down of the Pacific *might be in excess:* that its depression might be greater than its upheaval. For in no other way could we explain how such a multitude of islands should exist first at a level, and now more than 60 feet above the surface. Henderson's Island is about 60 feet above, and the Tonga islands of Capt. Cook, are about 20 or 30 feet. The theory, then, was not made for the purpose of fitting the facts—though it is a perfectly legitimate reason for adopting a theory, that you find it will explain all the known phenomena which no other theory will explain.—Still, it is somewhat more satisfactory if the principle was not formed expressly to suit the facts of the case. I argued that if there was an equal amount of upheaval and depression—supposing a motion of oscillation—a movement up as well as down—to take place, large masses of coral will be raised above the level of the sea; and that, unless we assume that the downward movement is in excess we are impelled to conclude the coral would not have remained on the level. For if it sink 30 feet in a century, the coral would grow up in that time 30 feet:—if it rose ten feet we should then find the solid ground of the coral ten feet higher up. If you reflect you will see that it is quite impossible to have so vast a number of islands just on a level without supposing the sinking to be slightly in excess; and when you find that this will explain the formation of attols and encircled islands, you must be skeptical if you reject the evidence in favor of it; especially when it is ascertained that in Greenland the land is settling—that there is a small subsidence in the Bay of Baiæ—at the mouth of the Indus, and along parts of the coast of South America. But what shall we say when we are forced to conclude that, not only must there have been a sinking down of the floor of the ocean to bring all its mountains to the same hight, but that all must have gone down so gradually as *never to sink one hundred and twenty feet at once?* For if there had ever been a fall of 120 feet the corals never more would have grown; all would have perished, and no new ones would spring up. The whole process of subsidence then must have gone on at a very gradual rate—not more than a few yards at any one time.

But when islands are rising (and we find that a large proportion of the islands in these seas are volcanic islands, or that in some part of them are volcanoes in active operation,) in this case we have coral reefs, but they do not encircle the islands; but we shall have a formation called by Darwin, *fringing reefs;* reefs fringing the shore as near as the zoophytes could live. There is a small island off Sumatra overspread, at all hights from the coast to 200 or 300 feet above, with coral shells of the *tridachna.* At the same time this upheaval has not carried the island as far above us it must before have been below the level.

The coast of South America is one where no coral grows. Why it is that zoophytes will not live there is not perfectly explained, any more than why none grow in the Atlantic. The Atlantic is warm enough and has all the necessary conditions; but except on the borders of the gulf-stream no coral islands are found on the coast situated must favorably in the tropical region; at present we can no more explain this than why certain plants do not grow in the United States; why roses are not indigenous in the Southern hemisphere, &c. But in the geographical distribution of plants the Author of Nature has given certain laws; and so with the zoophytes. They do not flourish on the Atlantic coast. The coast of South America is a coast of upheaval so far as we can judge. There are volcanoes here, and animals and shells are found at various hights. Yet there are no coral islands. Then in Gambier's group, in Tahiti and the Friendly Islands and in the Dangerous Archipelago are attols which have flat tops; here we suppose there were stationary periods when the lagoons had time to fill up. Then in the Navigators' and in Cook's island the oscillating movement causes attols and upraised reefs. Then in another region, in Suilivan's Island and the new Hebrides—for a long way from North West to South-East, the upward movement is in excess. In New Caledonia we find an example of an excess in subsidence. Then in the volcanic islands, Java and Sumatra, there is a great line of upheaval under which the beds of coral and recent shells are raised higher.

One of the most remarkable ridges of *attols* is in the Laccadive and Maldive Islands. For several hundred miles in extent you find a series or circular assemblage of islets all of coral, some o them 30, 40 or 50 miles in diameter. So you may trace them along the coast of Africa and the Red Sea, and go over a large area 2,000 or 3,000 miles from North to South, and from 7,000 to 3,000 from East to West, and find the same alternations.

It is often a subject of wonder to geologists to trace the same shells in different countries. Thus in Siberia and Russia MURCHISON has found shells identical with those in England; and the same spe cies as the *Caryophyllia* and others may be found in the North of Scotland and in this State of New-York. Rocks are met containing this extinct species with fifty others; and they may be traced at least to Iowa and very likely to the Pacific. It is a matter for wonder and marvel that these same species should flourish over so large a space of the globe as from Siberia to Iowa: yet it is nothing to the extent over which masses of limestone are now forming. But if you penetrate to a little depth all the interstices will be found to be filled, the carboniferous lime will be found as solid as any limestone, and all its organic texture will have disappeared or can only be discovered by microscopic examination. So is it with the old rocks at Trenton and Niagara which are of most minute texture; so that it is not true that the extent of the old limestone was on a grander scale than what is now exemplified in the present state of the globe.

LECTURE V.

ORIGIN OF COAL.

In speaking of the different strata of which the Earth's crust is composed—those at least which contain organic remains—I spoke of them as so many volumes of History—as so many monuments of the ancient states of the globe; and of their different structures as being so many leaves of these volumes. All that I can do in this short course of lectures is to take down at random, first one and then another of these volumes and endeavor not to give you any idea of the contents of the whole but just to express something of the method employed in the attempt to decypher these ancient memorials of the Earth's History. Now the volume which I intend to take down to-night is that which we term the *Coal formation;* and I shall speak of it only so far as to show the relative position, and the stateof the different periods when they were deposited beneath the water.

Now when I term this formation *Coal*, I merely mean this assemblage of strata which rests on the Older Sandstone, and in which is found that valuable fuel we call coal; and although the quantity in which it is contained is very small in comparison with the bulk and volume of the other strata, there is still great interest and importance attached to it. We see that in going from the highest to the lowest beds yet discovered, the coal occupies quite an ancient position—one indicating a formation low down in the Sea—as we have above it the most modern formations. We have first the Post-Pliocene, then the Tertiary formation, then the Chalk, which is made up of calcareous matter formed mostly, at least in Europe, from decomposed shells and coals and of those green marls which are found in New Jersey and are of such extensive use in Agriculture; then we have the Jura limestone or Oolite, in which also are masses of coral like the common coral reefs: below this are two other groups, of which I shall not speak at present, and lastly we come down to the Carboniferous or coal-bearing stratum which rests upon the thick sandstone beds, or the limestone containing corals and which like every other formation contains species of animals, shells and plants of different specie, from these immediately antecedent or following. Below this again we see limestone and shale, which enter most largely into the structure of the rocks of the State of New-York and which abound in fossils.

Now a great change must have been experienced before the coal period, when the fossils were deposited. I am indebted to Mr. Sopwith, an eminent civil engineer, for copies of some models prepared by him of those sections, which are faithful and accurate representations of actual localities, as has been fully verified by Dr. Buckland and myself in examinations which we made last spring. The different strata of sandstone, shale and conglomerate of which the carboniferous formation is composed, are here represented. The sections represent facts ascertained in cutting perpendicularly through the Newcastle coal district. They are not hypothetical but are founded upon exact measurement. In one of these sections you see the dip of the beds is at an angle of 20°, while the slope of the valley is 40°. In the other the dip is 50° and the slope of the valley in the same direction is 20°. In these two cases, therefore, the relation of the slope of the valley and the dip of the beds is reversed. In both cases, also, the slope of the valley and dip of the beds are to the South. To those who are not acquainted with these technical terms I may say that the deviation from a horizontal plane of the beds is called the *dip;* while the *strike*, as it is called, is the extension of the strata in a direction at right angles to the dip. In this case, as the dip is to the South, the strike must be from East to West. The flexures of the valleys depend on their inclination relatively to the dip; and these two sections cut through beds of coal and shale and sandstone—the shale being indurated clay—are illustrations of cases in which the two strata come up to the surface according to the various relations of the slope of the valley and the dip of the bed. It is a rule among miners that when the dip of the beds is less steep than the slope of the valley in the same direction, then the V's, as they are termed, will point upwards, those formed by the newer beds appearing in a superior position and extending higher up the valley. But when the case is reversed, and the dip of the beds is steeper than the slope of the valley, then the V's point downwards and those formed of the older beds appear uppermost. These rules may often be of great practical service in many cases. For example, suppose a miner first to begin his operations in one valley with the structure of which he is familiar. If he should sink his shaft through the formations above he would come to the coal which is below. But suppose one unacquainted with these rules which I have been explaining, to go to another valley; and in England he might easily go to such a valley, for these cases, as I said, are not hypothetical. He might, continuing along the same side of the hills as he had seen in the other valleys, where he observed the same *out-cropping*, as it is termed, of the coal seams, suppose, reasoning from his former experience, that he might begin his workings in the bed at the higher part of the valley with the expectation of coming down to the other bed. But he would be disappointed, as you will readily see by observing that the uppermost bed is lowest down in the valley, and the lower bed is the highest up. This you can easily trace with your eye upon these sections. An acquaintance with these rules and their application is of the greatest importance to those speculating in mining transactions. In the coal field of Pennsylvania, to which I shall presently allude, near Pottsville, I saw an exemplification this year of the two cases alluded to—when in the coal of the same valleys the V's in some cases pointed one way, and in the others in the opposite—the dip and slope being both towards the south. There is nothing more singular or which has struck me so forcibly in respect to the coal fields of this country as their close resemblance to those of the north of Europe, and of England in particular. I have traveled on the north side of the Alps towards the south, and have been astonished to find minerals of fossil of entirely distinct genera from those met with in the Pyrenees. Nor have the chains of mountains any thing to do with this remarkable change—for the beds were formed at the bottom of the sea before the mountains existed. Observing this great change, then, in the short passage of a few hundred miles, it seems to me most surprising that in passing, at the distance of three or four thousand miles, from England to the Apalachian chain in Virginia, we should find the coal measures the same as those we left behind, represented in the red sandstone, and containing white grit and slaty shales, and clays not slaty, and beds of conglomerate containing quartz pebbles.

It is generally admitted by geologists that *all that fuel which we call coal is of vegetable origin.* If there has been any dispute with regard to this, it was settled when a portion of the Newcastle coal some years ago was submitted to a microscopic examination. After cutting off a slice so thin that it should transmit light, it was found that, in many parts of the pure and solid coal in which geologists had no suspicion that they should be able to detect any vegetable structure, not only were the annular rings of the growth of several kinds of trees beautifully distinct, but even the medullary rays, and, what is still more remarkable, in some cases even the spiral vessels could be discerned. But besides these proofs from observing a vegetable structure in the coal itself, there has been found in the shales accompanying it, fern leaves and branches as well as other plants, and when we find the trunks of trees and the bark converted into this same kind of coal as we find in the great solid beds, no one will dispute the strong evidence in favor of the vegetable origin of this coal. If we find a circumference of bark surrounding a cylindrical mass of sand, we know that it has been a hollow tree filled up with sand, nor can there be any doubt that the coal is formed of vegetable matter. No less than three hundred species of plants have been well determined by botanists, some of whom have devoted a great part of their lives to this study. From this it is to be inferred that the carboniferous formation of Europe and America is made up of comparatively recent plants. I will allude to three or four of the most peculiar facts that lead to this conclusion.

In the first place the boughs and leaves of Ferns are the most frequently and strikingly met in America as well as in Europe. So perfectly have they been preserved that there can be no doubt that they are really ferns; and in some cases even their inflorescence has been preserved at the back of the leaves. Where we have not the flowers and prints remaining we have found it possible to distinguish the different species of fossils and ancient ferns by attending to the veining of the leaves. At least one hundred species are determined in this way. The most numerous of these vegetable veinings are those which have been called *Sigillaria*—or Tree Ferns. Their stems are found to be fluted vertically and in the flutings are little stars—as it were—each of which indicates the place where the leaf was attached: and it is evident, as M. ADOLPHE BRONGNIART has shown, that they are recent Tree Ferns. One argument for believing this is that although the bark of these trees is so well marked that forty-two species have been described, yet there is never found any leaf attached; while we have in the same beds loose leaves in abundance which have no trunks. The natural inference is that they must have belonged to the arborescent ferns; as for instance the section named *Caulopteris* is admitted by all to have belonged to this species. This fact is also important because the tree ferns and especially the *Caulopteris* are now known be exclusively the inhabitants of a warm and humid climate—much more hot and moist than in those parts of the globe where coal now abounds. For we find coal not only in England and Nova Scotia but as far north as Melville's Island and Baffin's Bay, in a climate where the growth of such fern plants is dwarfish and stinted. It is evident that when these vegetables existed there must have been a warmer, and probably a more equable climate than now even in warmer latitudes.

For even in the tropical zones, where we meet with large developements of the *Caulopteris*, their general growth is much smaller than these fossil remains. So is it with all the plants of the fir tribe; many of them of which we find fossil remains in the coal now exist only in the Southern latitudes, where no coal is found. The *Araucaria* we now find in Chili, and other warm parts of the globe, but never at the North, where its fossils abound in coal. The gigantic plants of the *Equisetaceous* tribe are also found to be much smaller now in hot latitudes than are their fossil remains. This would lead to the inference that the climate in Northern latitudes was then much warmer and more moist than it is now in any part of the globe. The same thing is made evident by a comparison of these fossil *Sigillaria* with those which now attain their greatest size in the islands of the Pacific. I have also found several plants, as the *Asterophyllites* in the Apalachian chain, this year, which I have also from Nova-Scotia and Europe, and which cannot certainly be referred to any living families. These all, however, bespeak a terrestrial vegetation, though occasionally found mixed with marine shells and corals.

Another class of fossils common in coal shales is the *lepidodendra*—somewhat allied in form to the modern *lycopodiums*, or white mosses. Though the mosses of the present day are never more than mere shrubs even in the warmest regions, yet at the carboniferous period they attained an enormous developement, being 50, 60 or even 70 feet high.

There have been two theories to explain how these plants could have been carried into the sea, estuaries or lakes, and drawn beneath the water and accumulated in the strata so as to form coal. One of them asserts that the plants must have been drifted and buried in the water, since we find them intercollated between different slates or shales: just as plants lie between the leaves of a botanist's *herbarium* and are pressed together, so have these ferns been found flattened between the seams of shale. They have been carried from the place where they grew, drifted out to a certain distance, water logged and sunk in the mud and other strata deposited above them, so as to form this intercollation between the different leaves of clay.

But many believed, from seeing the roots, that the plants grew on the spot where we now find them. But when we come to observe that these roots terminate in different strata, it will seem evident that they were carried down, sunk and stuck in the mud as snags are now in the Mississippi. In the quartzose sandstone at St. Etienne, near Lyons, are found a vast number of these *Lepidodendra* and *Sigillaria*. No one apparently can doubt that these drifted to their present position, and that they were afterwards covered with sand brought down by rivers. Many appearances favor this hypothesis. Sometimes we find beds of marine shells, then vegetable matter and then a mixture of fresh water and marine shells.

But though these facts may be thus explained the discoveries that are being made lead geologists to come round more and more to the opposite view of the case—to the hypothesis which refers the growth of large beds of coal to the increase on the spot—after the manner of peat, as it is seen in cold and dark climates. This may appear contradictory to what I said with regard to a change of climate since the carboniferous era: but it is not necessarily so. The opinion of WERNER, confirmed by the speculations of BRONGNIART, led me to believe contrary to my early impressions, that by far the greater part of the coal had grown in the spot where it is found. Accumulating like peat on the land, the land must have been submerged again and again to allow the strata of sand and mud to be superimposed as we now find them.

In excavating for coal at Balgray near Glasgow, in 1835, many upright trees were found with their roots terminating in a bed of coal; and only three years ago, in cutting a section of the Bolton Railroad in Lancashire, eight or ten trees were found in a vertical position; they were referable to the *Lepidodendra* species and allied to the *Lycopodiums*, or club mosses. All were within 40 or 50 feet of each other, and some of them were 15 feet in circumference at the bottom. The roots spread in all directions and reached beds of clay, and also spread out into the seams of coal.—There is no doubt that these trees grew where they are found and that the roots are in their original position. The seam of coal has possibly been formed of the leaves which fell from the trees. This is a singular fact: that just below the coal seam and above the covering of the roots was found more than a bushel of the *Lepidostrobus*—a [illegible] not unlike the elongated cone of the fir tree. [illegible] een imagined that the *Lepidostrobus* [illegible] t of the *Lepidodendra*; but here they are [illegible] ith other trees.

Under [illegible] seam of coal in Wales is found the fire clay—a sandy, blue mud, abounding in the plants called *Stigmaria*. First is the seam of coal, then the fire clay, then another seam of coal, and then the sand stone. In one part of the Newcastle coal field about 30 species of *Sigillaria* were discovered: the trunks were two or three feet in diameter. They pierce through the sand in a vertical direction, and after going for some 11 feet perpendicularly, the upper part bends round horizontally, and extends laterally into the sand,—and then they are so flattened by the superincumbent strata, that the opposite barks are forced within half an inch of each other. The flutings are beautifully preserved in the flattened horizontal stems. Here we had an ancient forest growing in a bed of clay—buried in some way with sand to a certain depth, and then the upper part was bent and broken off by the water current, and buried in layers of shale and sand. There are many cases of this kind in Wales, where the roots of the trees evidently preserve their original position. Mr. LOGAN, an excellent geologist, has examined no less than 90 of these seams of coal in Wales. They are so exceedingly thin that they are of but little value in an economical light—yet, they are just as important for geological purposes, as if they were thick strata. Under every one of the 90 he has found the fire clay, a sandy mud containing the plants called *Stigmaria*. It was discovered years ago that this fire clay existed with the coal mine; but it was not known that it was the floor of every coal seam, and not the roof, which contained this plant in a perfect state. The *Stigmaria* appears in the under clay (to use the term employed by miners,) a cylindrical stem, from every side of which extend leaves—not only from the opposite sides—but from every side; they appear like tubercles, fitting on as by a joint. They radiate in all directions in the mud, where they are not flattened like the ferns. Had they been we might have had leaves in two directions, but not on every side. These plants resemble the *Euphorbiaceæ* in their structure, and in some respects are analogous to the Coniferous or fir tribes. In their whole structure they are distinct from all living genera or families of plants.—In one instance a dome-shaped mass was found with stems and leaves—some of the branches being 20 or 30 feet in length and sometimes longer. It has been thought by Dr. BUCKLAND and other geologists, that these plants either trailed along in the mud at the bottom of swamps, or to have floated in lakes like the modern *Stratiotes*.

After Mr. LOGAN had arrived at this remarkable fact, we became particularly desirous to know if the same fact was true in the United States. When I arrived here in August, I had no idea how far it was true, yet it was known the *Stigmaria* did occur; and my first opportunity to inquire into the fact was at Blossburgh, in the Bituminous field in the Northern part of Pennsylvania. My first inquiry of the geologist was whether he found Stigmaria there. I was answered in the affirmative; and on asking if the plant occurred in the *under clay*, he said we could soon settle the point. He had one of the mines lighted up, and the *only plant we could find in the under clay was this Stigma ria:* it existed in abundance—its leaves radiatin in all directions, just as in Wales, more than 4000 miles distant. The same crutal appearance was preserved. In the roof of the coal seam were seen different species of ferns,—*Sigillari* and *Calamites*, just as in North Carolina and in Wales.—Afterwards another opportunity occurred in the Pottsville region of Anthracite coal. Professor RODGERS, the State Geologist, who, though well acquainted with the strata of the district, was as anxious as I was to know if the rule would hold good, examined first at Pottsville and at Mauch Chunk, when the same phenomena were observed. In the first coal mine we came to, the coal had all been quarried away (for the work was carried on in open day) and nothing but the cheeks of the mine remained. The beds, as they have been horizontal, are now not vertical, but have gone through an angle of a little more than 90°, and turned a little over; so that what is now the under side was originally the upper; therefore the cheek on the left side was originally the floor of the mine. We now looked at the lower cheek; and the first thing we saw was the Stigmaria, very distinct; on the other side, but a little way off, were ferns, Sigillariœ, Calamites, Asterophyllites, *but no Stigmaria*. So it was at Mauch Chunk, where we found one 30 feet long with leaves radiating in all directions. At this place there is a bed of Anthracite nearly 60 feet thick—a magnificent accumulation of vegetable matter, to which there is nothing comparable in Europe. Except in one place it is perfectly pure.

It has now been ascertained for many years that Prof. EATON was quite correct in affirming the Anthracite and Bituminous Coals to be of the same age. This is shown not only by their relative position with regard to the red sand-stone, but from the plants found in both being identical.

All the coal fields, therefore, may be regarded as one whole, and the question will occur, How did it happen that the great floor was let down so as to prevent the accumulation of coal and yet plants of so different textures should be found in it? It has been suggested that these plants grew in swamps; and it is possible to imagine that there may have been morasses fitted only for the growth of the species of plants called *Stigmaria;* and that this marsh filling up, this and the other plants became dry, and the leaves accumulated one layer above another, so as to form beds of coal of a different nature from those that preceded. You know it is a common thing for shallow ponds to fill up gradually with mud and aquatic plants and at last peat and trees are formed upon them. A corresponding change is constantly going on in different parts of Europe—the same transition from bogs and marshes to a soil capable of supporting various great trees is taking place, and then the ground is submerged; for always, again and again, we must refer to this subsidence of the soil.

Many of you, I suppose, have seen the morass called the Great Dismal in North Carolina and Virginia; and you have probably had an opportunity, as I have, of crossing the northern extremity of it on a railway supported by piles, from Norfolk to Weldon. This is no less than forty miles from north to south, and twenty from east to west, covered entirely with various forest trees, under which is a great quantity of moss; the vegetation is of every variety of size from common creeping moss to tall cypresses 130 feet high. The water surrounds the roots of these trees for many months in the year. And this is a most singular fact to one who has traveled only in Europe, that, as is the case in the United States, trees should grow in the water, or surrounded to a certain hight by water, and yet not be killed. This Great Dismal was explored some years since by Mr. EDMUND RUFFIN, author of a valuable Agricultural Journal. He first calls attention to the fact that a greater portion of the vast morass stands higher than the ground that surrounds it; it is a great spongy mass of peat, standing some seven or eight feet higher than its banks, as was ascertained by careful measurements when the railroad was cut through. It consists of vegetable matter with a slight admixture of earthy substance, as in coal. The source of peat in Scotland is that one layer of vegetation is not decomposed before another forms. So is it in Chili, Patagonia and Terra del Fuego. Thus also is it in different parts of Europe, in the Falkland Islands, as DARWIN has shown. Thus, too, is it in the Great Dismal, where the plants and trees are different from those of the peat in New-York. It is found on cutting down the trees and draining the swamp and letting in the sun, that the vegetation will not be supported as it was before beneath the dark shade of the trees. In the middle is a fine lake, and the whole is inhabited by wild animals, and it is somewhat dangerous to dwell near it by reason of the bad atmosphere it creates. It is covered by most luxuriant vegetation. We find in some places in England that there is a species of walking mosses, which are sometimes seized with a fancy to walk off from their places: the moss swells up, bursts and rolls off, sometimes burying cottages in its path. In some places this peat has been dug into and houses have been found several feet below the surface—curious antiquarian remains. In the same manner the Great Dismal may spread itself over the surrounding country.

In speculating upon the probable climate of the Carboniferous period, it is believed that we have only to imagine a different distribution of the land over the surface of the planet than that which now prevails, to produce such a warm and humid climate as must have prevailed when these plants flourished which form coal. It is the existence of high lands near the pole which produces such great cold. If these mountains were to be transferred to the tropical regions, it would immediately lower the temperature of all climates of the earth. Now every one who has attended to the study of rocks and fossils sees at once that the present physical geography of the globe has no reference to its ancient condition. Seas once occupied a large portion of what are now continents, and we also find evidences of marked change in the Carboniferous and other strata. In the limestone accompanying the coal we find corals and shells, strongly indicating a higher temperature of the sea, as the plants shadow forth a higher temperature in the atmosphere.

I have been favored with a map illustrating these points by Prof. Hall, one of the State Geologists engaged in surveying this State, whose labors will soon be made public. And here I cannot avoid saying that I have been over much of the ground which they have surveyed, and it gives me great pleasure to bear testimony to the accuracy of their labors, to the great pains they have taken, and the science with which they have conducted the survey. I look forward to the appearance of their work, embracing the results of their labors, as *an era in the advancement of science;* and the patronage which has been afforded by the different States of the Union to these surveys is much greater, in proportion to the population, than any European power has ever extended to the advancement of geological science. When we remember, too, the complaints that may be heard in different parts of the State that the geologists have failed to discover any mineral wealth, even in an economical point of view, these scientific researches are of high value, though their greatest interest arises from the promotion of the knowledge of the structure of the globe.

But merely in estimating the mischief they have prevented, we shall see an ample remuneration for all the expense attending the survey. I have been told that in this State alone more than a million of dollars have been expended since the Revolutionary War in boring for coal in formations were *it is impossible to find any*—below the carboniferous strata. I should not, to be sure, have ventured to generalize from Europe as a type and say that the rocks in the crust of the earth occupy the same relative position here, and that coal would be found always in this country under the same conditions as in Europe. But when for twenty years or more we find coal accompanied by the same plants, and that no valuable fuel has ever been found under any other circumstances we should be safe in saying that none could be found in the older strata. If we begin in the newer beds we may come down to the coal, and find enough coal to pay the expense of boring for it. But if we begin in the strata beneath the carboniferous we should certainly never reach the coal until we had bored through the whole earth: we might find it at the antipodes but not before.

Thus complaints are made against these geologists not only that they have found no coal, but that they have passed sentence of sterility upon the State, for they say that through all time no coal shall be found within its borders. And when we reflect on the enormous sums that have been wasted upon strata more ancient than the coal, in searching for coal, we shall see the great saving made in consequence of this survey; for when all its maps and sections are published it will be seen how impossible it is to find coal in these more ancient beds. This is a kind of advantage which is never easily appreciated: because, to prevent mischief is never so clear and palpaple a benefit to the multitude as to find mineral wealth. But one of the greatest advantages which have resulted from these surveys in England, and it will be among the greatest here, is the prevention of this rash and absurd speculation to find coal in strata below that in which those plants known to be essential to the formation of coal are found to exist: and after examining the whole ancient strata, both in the United States and in Europe, there has never been found a single bed of coal where these plants do not exist.

LECTURE VI.

FOSSIL FOOT-PRINTS.

I HAVE been asked by several persons who heard my last lecture, upon the Origin of Coal, if I could explain the difference between Coal and Anthracite; and as I then had no time to touch upon this subject, although my last lecture was prolonged beyond the limit which I wished, I will now speak of it in a few words. It certainly is a good question; but several persons have asked me whether, conceding the vegetable origin of coal, it may not be the *difference in the wood* which causes the difference in the coal: whether one kind may not produce the Coal and another the Anthracite. Now there is no doubt that, in the strata of the Earth, there is some variety in the character of the various Coals discovered, which may be owing to a difference in the original texture and composition of the different plants from which they were formed. But this, nevertheless, is not the cause of the difference between Anthracite and Bituminous Coal, as they have been produced by the same plants. There is no doubt that the Palm, and other Monocotyledonous plants, and bamboos, reeds, &c. would give a kind of coal to a certain degree different from that produced by the fir and other Dicotyledons. But as precisely the same assemblage of plants is found in the Anthracite and Coal, it cannot be in this way that the difference between these substances is caused; and the conclusion to which the geologist and chemist have come is this: that *Anthracite has once been Bituminous Coal*, but has lost its bituminous matter by its escaping; that the volatile part of it has escaped and the wood has become gradually converted into coal by the loss of its oxygen—vegetables being composed of carbon, oxygen, and hydrogen. The vegetable matter losing first its oxygen loses also in the combination some portion of its carbon, forming a carbonic acid which escapes from the wood, often as a pure gas—as may be seen in bubbles which rise from the bottom of pools of water: it is thus converted into coal by the loss of its oxygen; and this conversion is so gradual that there are found in the Earth woods in every stage of the change—both in that state when they are called *lignites* and when they have become perfect coal. We find, too, all the intervening forms between wood and coal, and then all between coal and anthracite. This is caused again by the loss of the hydrogen which escapes in combination with carbon, in the form of carburetted hydrogen gas—the same substance that we are now burning here. You are aware that this gas cannot be produced from anthracite because in that the operation has already taken place: it is manufactured entirely from bituminous coal. This volatile, inflammable gas may be seen to escape from rents in the Earth—natural rents from which this carbo-hydrogen issues; and if the coal below be examined it will be found to be in process of gradual change. But there is one remarkable fact observed in this country: that, in the coal region of Pennsylvania for example,—and this has been especially pointed out by Prof. RODGERS in his survey of Pennsylvania—the anthracite is found to be purest in the most disturbed part of the mountains; and it is half bituminous when you get into the regions that have been slightly disturbed—in the western part of the State; and when you reach the perfectly horizontal coal district—that where there has been no disturbance, no shattering and tearing up of the mountains—there the coal is purely bituminous, not having lost its hydrogen. Some have suggested that this is owing to the rending and fissuring of the rocks in the disturbed region, in which all the volatile matter would have escaped more easily. Of this there is no certainty. But the general fact is undoubted—that in proportion to the disturbance, overthrow and bending of the strata—some of which have been folded back upon themselves—do we find that the conversion into anthracite from pure carbon is most complete.

The next subject of which I shall treat is that of *Fossil Footsteps* found in the formation which we call the New Red Sandstone. Its position in the series is as follows:

1. Chalk.
2. Oolite.
3. New Red Sandstone,
4. Magnesian Limestone,
5. Coal.
6. Old Red Sandstone,
7. Silurian Group.
8. Granite.

In the upper part are found organic remains in great abundance and in the red and white sandstone there were found about seven years ago in

Germany the remains of footsteps—prints apparently made by the feet of quadrupeds (rudely represented in this drawing) [exhibited.] Often five or six pairs of these are found in one track. They are found near the borders of Bohemia at Hessberg; and their discovery created at first a prodigious sensation in Germany because some imagined that the animals were a sort of *extinct form, perhaps, of man*, or some prototype of man. The hand-like form of these tracks, resembling in some degree the human hand, created great astonishment. The largest track was about eight inches long; before each of these large tracks is a small one which is referred to the fore foot of the creature. There were observed four toes and one other which resembled a thumb. In one track that was found on the right, in the next on the left, and so on; and to whatever distance they were traced they were found thus to alternate right and left. No doubt whatever is entertained that these represented the steps of some animal imprinted on layers of clay when in a soft state. They stood out in relief upon the under side of the slabs of sand-stone when taken out; because this sand-stone was once in the form of loose sand, and was thus deposited in the hollows of the clay below; so that it would present the appearance of a cast moulded in the hollows of the subjacent clay, and we should have a perfect cast in relief of the footsteps of the animal as it walked on the clay.

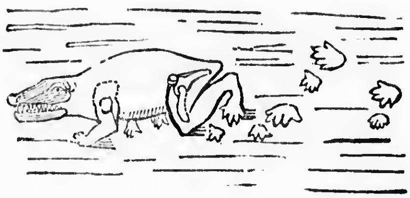
Some conjectured that this animal belonged to the *Marsupial* or Kangaroo tribe, because the hind feet of this animal are remarkably large in comparison with its fore feet; and it has feet also very much in the form of the human hand. Others believed it to belong to the Crocodile tribe; and Prof. LINK early conceived that it belonged to the *Batrachian* or Frog family. While this discussion was going on in Germany—or but few months after this—similar footsteps were found in the Red Sandstone of the same age in England, at Storeton Hill in Cheshire, not far from Liverpool, on the banks of the Mersey. These salient footmarks were observed on no less than five distinct ranges or layers of sandstone; there were five thin layers of clay, and resting on each was a thin white or yellow quartzose sandstone, which presented these footsteps precisely like those found in Germany. It had been previously ascertained from the position of these beds, and the other fossil rocks in question, that they were of the same age with those in which the footprints were found in Germany. They were found of several sizes; one in which the larger footstep was eight inches in length; another in which it was twelve; this was called the *Cheirotherium Herculis*, on account of its great size. The tracks were about fourteen inches apart. In the Museum at Liverpool is preserved a long slab of sandstone—as long as this staff (some ten feet) in which the prints are so beautifully distinct in relief that you would suppose they had been made by the chisel of the sculptor. In some slabs preserved in the British Museum you may see prints of this shape [exhibited] which are evidently casts of the small cracks below. The clay having shrunk, these cracks were opened by the heat of the sun: so that when the loose sand was deposited in the footprints of the animals, it found them filled with these rents in the clay; and when they came to be taken up, these cracks are found to be in relief, as well as the footsteps. The same things are found in the same beds of England; and in this red sandstone, which is found all over Cheshire and other parts of the kingdom, are found ripple-marks—parallel ridges, marking the ripple on the beach of the sea at low-tide.

It was remarked when reasoning upon the subject in London, and in the discussions of the Geological Society, that these footsteps must have been made by an air-breathing animal; as no animal which existed under water could make such distinct foot-marks, not being heavy enough in that fluid; they were pressed down by the weight of an animal walking in the atmosphere, and therefore at low tide. And nothing is more common now than to observe the tracks of various animals upon the beach at low tide. I had an opportunity myself of observing this in the islands near Savannah in Georgia. At low tide I have seen the whole beach covered with the tracks of the Opossum, Racoon and other animals; and in many places after tracing these tracks some hundreds of feet, I came to places where the quartzose loose sand of the low cliffs of the islands had been blown by the wind only a few hours before while the tide was down; still there had been time for the tracks to be made and for the wind to blow the sand over, and in some places the tracks were thus obliterated, some entirely and others only in part. We have then only to suppose a submergence of a coast so situated carrying down this sand, afterwards that it was consolidated by ferruginous or other matter, and we should have a counterpart of this. Take up a slab of the common sand and it would present the same marks of the racoon and opossum.

At the same time that these fossil remains were discovered by Prof. KAUP who devoted considerable attention to the subject, Mr. OWEN procured from Warwick several fossil teeth of a conical form; and being engaged at the time in investigating the internal texture of the teeth of various animals, he cut away a thin slice and subjected it to examination by a powerful microscope, and he was surprised to find that this tooth, found in the New Red Sandstone, No. 3, differed greatly from those of all the other reptiles found in No. 2, or the Oolite formation. This Oolite has been called the *age of Reptiles*, because we have in it so many of the *Terebratulæ*, and reptiles—flies, fish, lizards, *Ichthyosaurians* and *Saurians* of various kinds—not one of which has a texture resembling in the least degree the texture of those found in the New Red-Sandstone. He made a representation of a small part—one-fourth of a tooth, which he has allowed me to copy. [Exhibited.] You see that its texture recalls the appearance of a section of the human brain; it has the same convolutions, formed by the dentine and pulp of the tooth; the animal that exhibited so remarkable a structure was believed to be distinct from any living species. Supposing this to be the case and becoming greatly interested in this discovery, Mr. OWEN applied to the German Professor KAUP, to have one of his fossil teeth sent from Germany that it might be dissected, and thus that it might be ascertained if it had the same structure as those found in England. This was done and the *same remarkable texture was observed*. Thus we have in both countries—five hundred miles apart—fossil teeth, found in the same rock and having the same structure, entirely distinct from that of reptiles in other formations. It was evident that they had belonged to reptiles—for they were different from any belonging to quadrupeds or fish. It was thus believed that they were a reptilian class of a new and before unknown family.

The next discovery made in the rocks of this very age, and in the same series of Sandstone in which the impressions of footmarks were found, was of parts of the scapula, femor and pelvis of more than one species of this animal. It had received the provisional name of *Cheirotherium* or *Beast of the Hand*, from the shape of the imprinted footstep. The question now was whether the teeth and the bones could belong to the *Cheirotherium*.

Mr. OWEN remarked, after examining some of the bones of the hinder extremities and comparing them with the bones that evidently belonged to the anterior extremities—to the fore arm, found in the same place and probably belonging to the same animal—that *there was as great a disparity in the relative size of these bones as in the marks of the hind feet compared with those of the fore feet*. Soon after a portion of the jaw was found and Mr. OWEN was able to construct a skeleton of this animal—to restore in imagination something of the form of the animal that once may have walked so as to produce these lines of foot-marks, by bringing its hind foot forward so as to make an impression close to the last one of the fore foot. This figure is a representation of the animal and the position of his tracks:



These parts were found when I left England nine months ago and it is probable that more have been found since that time, for all these discoveries have been made within the last twelve or fourteen months.

It was therefore now clear that there had existed, at the period of the deposition of this stratum in which these impressions are found, several species of animals which correspond well, in relative dimensions, with the size of the several sets of footsteps found in Germany and England. At least three distinct sizes were found—teeth belonging to three distinct species. They were called *Labyrinthodon* from the labyrinthine convolutions in the structure of the tooth.

The next step made in England was to ascertain whether this *Labyrinthodon* was an air-breathing animal or not. Now OWEN has shown from the structure of some bones in the lower jaw, and also of one in the upper, that there was an orifice which implied a nasal cavity, placed as in air-breathing reptiles of the division *Batrachia*. For it is possible from the bones to discover whether the animal breathed by gills, or at least by *bronchia*, for in that case the opening would extend to the nostrils; whereas if the animal breathed air, the cavity would be placed much farther back—nearer the back of the head. We are able to show that this *Labyrinthodon* had been an air-breathing animal, and must have been able to walk along the side of the retiring water.

You are aware that reptiles are distinguished into four great divisions—

1. *Saurians,*
2. *Chelonians,*
3. *Ophidians,*
4. *Batrachians.*

The first embraces crocodiles, alligators, lizards, &c.; the second, tortoises, turtles, &c.; the third, snakes and boas, and the fourth frogs, newts and salamanders. Now it is quite evident from its osteology that this creature belongs to the *Batrachian* order—that it is a gigantic frog, as large as a bull, and the Cheirotherum perhaps was as large as an elephant. The salamandrine reptiles are represented in tho living order by creatures of a comparatively small size. In this country there is an aquatic salamander among the Alleghanies two feet in length—much larger than any that we have in the old world, except one which is found in the island of Japan, called tho *Salamandra Maxima* exactly resembling a frog. It is very singular that this animal should have been found in a lake in a volcanic crater in that island. It is now in Leyden, where for eight or ten years it has been in the Museum. There were two procured, a male and a female, about four feet in length. Only one was brought home; and to prove that they are carniverous I need only mention that on the passage the *male devoured the female,* so that we have only one in the Museum. They are fierce, voracious creatures, and it is very singular that they should be found in the crater of a volcano; because there has always been a story—from the most remote period—as long ago, at any rate, as the time of Aristotle—that the Salamander was inconsumable; and there have been depositions in great numbers made before most respectable magistrates, some of whom are now living, that these creatures have been seen to come out of a fire in which they had been exposed to the white heat of coals for two or three minutes perfectly uninjured. But after a full examination it turns out that this is entirely a fable.

I will now observe that although we have no complete specimen of either the *Cheirotherium* or the *Labyrinthodon,* we have still enough of their remains to leave no doubt of their character on the mind of any person. We have first in rocks of tho same age in Germany and England the same footprints. We have in both countries certain teeth of a most remarkable structure, peculiar to that rock to which belong the animals which lived at the period when these footmarks were made. We find the hinder extremities in each species as much larger than the anterior portions as the posterior footsteps are larger than those of the forefeet. And lastly we require air-breathing animals, and we find the structure of the nasal cavity such as to show that the *Labyrinthodon* was evidently an air-breathing creature.

You may be aware that in this country there have been found some remarkable tracks of birds in the Red Sandstone of the valley of the Connecticut; and Professor Hitchcock has embodied an excellent account of them in his final Report of the Geological Survey of Massachusetts, and has given some excellent plates not only of the extinct species, but also of the animals and birds that may now be found on the shores of the lakes of America. It appears to me that he has completely made out that several species of birds existed at that period which, so far as is known, is the same as Nos. 4 and 5 in which are found the footsteps in Europe; and he has found some as large there as an ostrich and others again of smaller size. The variety is considerable. He has found, too, the same ripple-marked figures—in which are seen casts of the skeletons of the cracks in the clay produced by shrinking. I have seen as near this as at Newark, examples of this sandstone ripple with casts of the cracks in the subjacent clay.—In England there are places where occurs clay which has been pitted over by small depressions as though it were done by a shower of rain. You can see that if rain falls upon sand it will cause a pitted appearance; and of such we find slabs containing casts which have been called fossil showers of rain; and I am inclined to believe that this is the origin of the appearance. And I think that upon this point Mr. Redfield and myself will agree—that in Newark we have slabs in which can be seen the same marks, not so exactly representing a shower of rain as those in England but still having a close resemblance to them. In this case the marks are in soft shale and we have pits; but when salient casts are found we have all the apparent marks of rain in relief like the footprints and casts of cracks in the clay. There are some beautiful remains of fish in the same strata in the valley of the Connecticut and in parts of New Jersey, some of which are upon the table. They are not in the samo beds as the footprints—but in the same strata—formed deeper under water.

But as I must not dwell too long on any one subject—as the course I am delivering is so short, and as I am desirous of treating as many subjects as possible—and having already spoken of formation No. 3, I pass the coal—of the *Flora* of which

I spoke in my last lecture—below the Red Sandstone to Strata No. 7, which we see abounding in fossils; and in no part of the world has it so magnificent a development as in New-York, though it occurs in greater thickness in Pennsylvania. But there is at least no part of the world that has been investigated where we see the fossil character of the different periods so well made out as in New-York. When we come to the subdivisions of this one formation, you will see at once that it forms as many groups as are represented in the other table. The first of these divisions was formerly called Transition—but now the Silurian Strata; because it is found mostly in Siluria, a region on the borders of Wales, composed of the border counties of Wales and England. It has been well studied and elucidated by my friend Mr. MURCHISON. For this section [here exhibited] I am indebted to Professor EMMONS and Mr. HALL of the State of New-York. It exhibits portions of the results of their joint labors; and I have had the advantage of going over the region and seeing the beds in the order they are here represented.

First of all we have what is called the Mohawk group, which is 1200 feet thick in the state of New-York and thicker in Pennsylvania; for the thickness depends on local or accidental causes. If the material of which it is composed be coarse the strata will be thick. The fine sand will be floated farther out to sea. In this strata occurs the Trenton limestone—with trilobites and other species of fossils. We have in this strata some extinct species as the *Lingula* and others that must have lived in the seas. The *Graptolite* is found in the old rocks, and is a species of zoophyte related to the *Pennatula*. It is an example of an extinct form only found in ancient rocks, never beyond the Transition or Silurian Strata. When we pass to the Red Sandstone we have a resemblance to the more modern rock, of which I have before spoken, in which are found the fossil foot prints. It is called the Ontario sandstone because it is found along the borders of Lake Ontario. The lower part of the Cliff at Lewiston, in the Niagara District is the same bed seen horizontally; it is 60, 80 and in the lower part 120 feet thick. Of its exact position I will speak more at length in my next lecture; I only wish now to point out the order in which they follow. If you suppose yourself aloft in a balloon—looking down over that part of the country, it would present the appearance in this figure—in which a portion of the wood is supposed to be cut away so that the geological structure of the rock can be seen.

After the Ontario sandstone comes that which is called by Mr. VANUXEM the Protean group from the many different forms in which it appears. It contains the *Pentamerus*, an extinct species of bivalve shell. Sometimes it is also in the form of iron ore. This Protean mass is only about 50 feet thick at Queenston and Lewiston, though in some parts of the country it is probably thicker. It is found farther East and South. Passing, then, from the Mohawk limestone to the Ontario sandstone and thence to the Protean group, we next come to the shale and limestone of the Niagara district. These beds contain an assemblage of organic remains, as, for example, the Chain Coral—so called from the resemblance of its upper surface to a chain. It is a genus peculiar to the ancient rocks of Norway, England and the United States. When I say that each of these groups is distinguished by a different assemblage of animals, of which there are several hundreds in one, I would be understood to mean that some species have a wide, vertical range, as it is called. Some may live longer on the globe during its changes than others; and this would be expected when we consider that some species at present bear different climates with more facility than others: they are a sort of cosmopolitan species, which are found every where. Thus we find the same shells in the Hudson as in our seas and in the Baltic; the same may be found in the temperate and the tropical zones.

The same group which borders Lake Erie and is seen at Buffalo forms the Black Rock of Buffalo. It is called the Helderberg lime-stone, because in the Helderberg Mountains we have no other beds of limestone, and upon the fossils found in them I might employ the whole of eight lectures; and you might suppose that the whole of geology was embraced in their discussion. Still that is only one subdivision of this one stratum, and there are beds of Corals found in other lime-stone, and in the oldest Trenton lime-stone like the ancient reefs—the species being for the most part different in each. There are found in the same series of the Silurian strata in England corresponding lime-stones at different stages, and occurring in the position in which they originally grew. They have the point of attachment at the bottom of the stratum, and the upper part continues to be uppermost. Or if they are hemispherical, those which radiate, you must determine by the manner of radiation which is the base and which the upper surface of the coral, and thus determine whether it is in its original position or has been overturned. We often see them in their natural position, as they grew, one upon the other. In several cases we find them broken and thrown over, as if by the force of the waves. In both cases the same coral grew in one case at the surface in reach of the waves, and in the other near the surface; because it is known that corals do not grow in the deep, dark, cold, unfathomable abyss of the sea, but within 120 feet of the surface, enjoying the light and warmth of the sun. Some of these corals are as large as this table, as at Williamsville, near Buffalo. In following for a long distance, as may be done in England, Norway and Sweden, this strata of fine sand which has formed this group, you find no other fossils but the *Graptolite*, belonging to the zoophytes of which the living specimens are found in muddy bottoms. Beneath that fine mud is no example of fine sand being deposited, for it will not go on in deep water. If you consider the laws which regulate matter falling through fluids, you will easily see the truth of this: the doctrine of terminal velocities explains it. For example, if you let a bullet of lead one inch in diameter fall through the air at the density at which it exists at the surface of the earth it will never fall beyond a given rate; it will fall faster and faster from the hand until it reaches a rate of 260 feet in a second, when it will never fall faster; for the force of gravity is a constant force, but the resistance of the air increases in a geometrical ratio. So in water: a bullet would never fall at a greater rate than 3½ feet in a second; while it would fall 260 feet in air it will only fall 8½ in water. If you reduce the ball of lead from an inch to a hundredth part of an inch in diameter it will fall only one inch in a second instead of 8½ feet; and so we shall find that if it be still farther reduced its maximum rate of descent will be much less.

But fine mud such as large rivers deliver into the ocean, only falls at the rate of about two feet an hour. Now, suppose the mud to be directed into a current like that of the Gulf Stream for example, which runs at the rate of three miles in an hour—suppose it to be delivered into the ocean by the Amazon or some other great river, and thrown into this current, it would be carried 2000 miles by the Gulf Stream in a month, while it was sink- 600 feet, which is no depth at all in the ocean: and we have reason to believe that the influence of the Gulf Stream extends for at least 600 feet below the surface, as is shown by its action upon icebergs. I think Mr. Redfield will agree with me in saying that the action of the Gulf Stream on enormous floating masses of ice extends to that depth. When therefore the mud might be carried so far, I see no reason why it may not be carried from the Equator to the Pole by this influence.

I will now offer a few observations on the inferences which may be deduced from these fossils found in the ancient rocks, concerning the state of the globe at those very remote periods. Even the most trivial circumstances derive a great degree of interest from their mere antiquity—they become consecrated, as it were, by time. Those who walk in the streets of Pompeii will look with the deepest interest and the most lively curiosity upon the mere ruts left by carriages eighteen hundred years ago, which are now as distinct in their impressions as if they had rolled there yesterday: they will look with pleasure and interest on the scribblings in Greek of the soldiers, on the walls of the barracks, in this ancient city, which has remained buried under volcanic ashes since so remote a period. How much more interest will the naturalist feel when he examines the remains of creatures believed to have flourished on the earth—in water or on land—thousands of years ago—as he finds them in these rocks we have been considering.

Let us, then, endeavor to draw some inferences from the study of these animals, respecting the state of the planet where they lived—how far it was similar to, different from, that in which it now exists. Take first the *invertebrated,* and then the *vertebrated* animals. Here upon the table are the remains of *Trilobites,* of which there is a prodigious number in this country. It is an extinct form of *crustacea*—believed to be of the same form as that of the crab and living lobster, but of a genera now extinct. They are very characteristic of the ancient rocks in Europe and Asia: but they are never found in the newer rocks. Examine the eye—for it is a singular circumstance that the eye of some of these creatures is preserved in a most perfect manner in the fossil in the mud in which it was buried. You find that some species have a hemispheric eye—sometimes placed upon a pedal. Here is represented one consisting of a great number of *facets;* the living dragon fly has no less than 14,000 *facets* upon each eye. Some of the living crustacea have a great multitude and to some extent they are analagous to the ancient. These were intended—as we know by reasoning upon the habits and structure of living species nearly analagous—to enable them to see horizontally by these lenses. The *facets* are set so as to look in all directions except one which is supplied by the hemispheric form of the other eye. Hence it has been justly observed by Dr. Buckland, from an examination of optical laws and the eye of the extinct animal, that we see there was the same relation of light to the eye, and of the eye to light, at that remote period as now exists in every species. The ocean must then have been transparent as it is now; and must have given a passage to the rays of light, and so with the atmosphere; and this leads us on to conclude that the Sun existed then as now and to a great variety of other inferences.

If we turn to vertebrated animals, therefore, we have several species of fish, of which the parts found were called *Ichthyodorulite* before they were aware of their origin. It was supposed that they were some part of a fish; but they are now known to be portions of the first spine or darsal fin, of the genus of fish, like the living genera called *Cestracion*. A tooth in the jaw of a different species has been found in England in the upper part of the Siberian series. In this country geologists have traced the existence of analagous species of fish a step lower. In several of these subdivisions there have been found remains, but never *vertebræ* nor ribs or other parts of the skeleton; but bony tubercles, &c. by which Mr. Agassiz has shown that they all belong to a cartillaginous fish, like the sturgeon; in which the external parts are bony, while the parts which in others are bony in these are soft; something like the Crustacea.—Still they are as perfectly vertebrated animals as any others.

What is implied here in the existence in the rocks from this remote period of these creatures is, that they may yet be traced back to an organic beginning. We find here a type of vertebrated animals—not of a high order, not yet fully developed, nor yet of the lowest order. They have the vertebral column, with the spinal marrow terminating in the brain; they have organs of motion in the orbit of the eye. There must, then, have been vision, locomotion, circulation of the blood, a nervous system—in short, we have sketched in this vertebrated animal of the earliest period a great outline of the very skeleton which now appears in reptiles and mammalia, and in man himself; and this acquires the highest interest when we find this first outline of that plan of organization already in existence, destined, after modification at different periods, to reäppear in the inferior animals, and in man himself.

It has been a subject of marvel and of incredulity to many to account for the existence of so many races of animals and plants which are now extinct, which all preceded the creation of man on the Earth. It is often asked for what purpose could they have flourished; and this difficulty arises from the habit in which we are too apt to indulge, of imagining that all the works of nature are produced either to satisfy the wants or to minister to the instruction and amusement of man. But those who take a wide and philosophical view of the present state of the creation must meet with the same difficulty. Look at the animalculæ in a drop of water, and you might put the same question: Why do these exist in such myriads, of which nearly all are invisible? Look, too, at the thousands of shells and other fish with which the whole ocean teems, and which do not come under the knowledge even of the naturalist. When this question presented itself to the mind of our great Poet, in the exercise of his high imagination, he sees that beings might have looked over the world, though unbeheld by man. He even says that

> 'Millions of spiritual creatures walk this earth,
> Unseen, both when we wake and when we sleep,'

and had the existence of these countless creatures been known to him he might have imagined that they lived and moved under the eye of spiritual beholders, though man were not. And certainly the light now cast upon these periods by Science makes them as wonderful and sublime as could the imagination of him or of any other poet. For we find that these creatures, in such multitudes, and in such varieties, existed upon the Earth for ages, then disappeared—dying and giving place to other races which likewise for a time inhabited the globe. But they too perished and then came the period of vegetation—of coal; and all the creatures that before lived and flourished in the water gave place to other and new varieties. So succeeded many other changes—each greater than the first in the catalogue. Yet through all these periods of stupendous changes we find the same perfect unity of plan—the same infinite wisdom—the same great outline of organization. Throughout the whole universe and in all these ancient periods of the Earth's formation we see the same great laws prevailing—those laws of organic and physical life which govern all the revolutions of the animal tribes; at length we find superadded to these other osteological and physical organs; yet the type re-appears not only in the inferior animals but linked with the intellectual and reasoning powers of man; and we find him by the power of those thoughts that

> '——wander through eternity,'

taking a retrospect of all these great periods—examining their characters, one after another, until he arrives at the remotest period of animal existence and finds himself able to study their history and the character of their organization. Nor has he merely the power to decypher these records; but an inexhaustible, infinite store of such memorials have been written upon the great rocks and placed, for his instruction, in the solid framework of the globe.

When I speak of the laws that govern these successive changes, I am aware that some persons look upon the idea, that such revolutions in the organic world are governed by laws, as favoring the doctrines of the Materialist. But we may regard these laws—when given either to the animate or inanimate world—as exponents fully to express the will of the Supreme Being. A law cannot be referred to any thing material; it belongs not to the material creation; it is higher than the world of matter—it is spiritual in its essence and leads us up to the contemplation of one Immaterial and Spiritual Lawgiver.

But I will not dwell longer upon this subject, but pass to one more strictly geological; to the conclusions which we draw from finding the older rocks in a horizontal position. It is striking to find in Europe, in great parts of Russia, in Sweden and in this country these ancient strata in their original horizontal position. As to the manner in which whole portions of the country have been carried away and left great cliffs behind, I shall speak more fully in my next lecture. You may observe one strata resting on another on a level; and this may be owing to the depression of the sea, which has left them exposed, or, as I believe nearly all agree, that the beds themselves have been gently lifted up out of the ocean and raised to their present hight, where they remain in their horizontal position. It is thought by some that there have been alternate periods of repose and violence all over the earth; but it may be laid down as a rule that the more ancient the rock the greater is the disturbance that has been suffered; because in the first periods the convulsions were more violent than those which occurred at late epoch.

But whether we adhere or not to the opinion that there has been a great series of alternations—periods of violence and convulsion followed by long eras of tranquillity—one thing is certain, that, from the earliest period, we have no record of one such epoch—no knowledge of any such dissolution of strata—no such paroxysmal convulsion in the crust of the globe; and had there been any such occurrence, it would not be possible now to find the ancient fossiliferous rocks in their original position. As to the fact, it is true, that in general we find the older rocks have undergone the greatest convulsions; and this will be quite intelligible if we refer them to volcanic forces which always shift their points of principal developement. There have been volcanoes, as I stated in one of my early lectures, in districts where they are now extinct—and where there is left no vestige of volcanic explosions. After a long period of disturbance and convulsion the fires were spent and then succeeded a period of tranquillity. It may be shown, too, that in former periods there were more volcanoes than during the more recent; and, therefore, if we suppose a shifting of the principal points of developement, which were near the surface and attended by earthquakes, it would follow that in time they would extend over a great part of the Earth's surface, and we should find, as is the fact, in the more ancient rocks greater convulsions undergone. I should infer from the examination of all the districts in which these phenomena may be observed—from Iowa to this section and so through the Northern parts of Europe and Asia—that during all the successive periods there had been prodigious volcanic action; and that the areas of the volcanic districts during any one period had been limited to comparatively small portions of the surface of the earth.

With this observation I will conclude my present lecture; and in my next return to the consideration of the Niagara district.

LECTURE VII.

RECESSION OF THE FALLS OF NIAGARA.

You will have learned from what I said in my last Lecture respecting the relative position and the age of the different rocks of which the Earth's crust is composed, that the rocks of which the Niagara district is composed, and of which I then said something, belong to a period of great antiquity in the Earth's history. Below them is only one stratum in which may be observed traces of fossiliferous remains, and we may regard this group of rocks as the most ancient respecting which we have any authentic information. Though we are in the habit, therefore, of calling this the New World, from the great developement of ancient rocks and the remarkably perfect state and the richness of their fossils, it is to this New World that the geological antiquary is compelled to resort for a knowledge of the most ancient rocks. Not only the pyramids themselves, but even the lime-stone rocks out of which the pyramids are built, are things of yesterday compared with the ancient rocks found in this State of New-York. The rock of which the pyramids are made belongs to the upper part of what is called the *Secondary* series; the primary being the lower and formerly supposed to be older than any that contain fossil remains, though we now know that this is unfounded, and that they are igneous rocks that have come up at different periods. The fossiliferous rocks, however, were named Secondary as being supposed to be newer than the Primary. When some other fossiliferous strata were discovered in Germany—rocks with but faint traces of organic remains—Werner, requiring for them some new name to distinguish them from both the others, called them *Transition* rocks, because they seemed to form a passage between the crystalline primary and the earthy, uncrystalline, secondary rocks of Germany. In the first were found no organic remains while the latter teemed with them. But Werner went farther, and, finding that the primary and transition strata in the district he examined were highly inclined while the newer fossiliferous rocks were horizontal, he named these *flötz* or *flat* rocks. His nomenclature would then run thus:

Horizontal,
Transitive,
Secondary.

"A strange transition this," says an eminent English geologist, "from primogeniture to horizontality;" and in fact its strangeness is not its only objection; for, as I told you in my last Lecture, the fossiliferous rocks are, in many districts, no more horizontal than the transition rocks; and this may be seen through this country to Iowa—through northern Russia and Sweden. The others are not vertical there, as Werner found them in parts of Germany.

The appellation of Silurian [illegible] given to these rocks by my friend Mr. M[illegible], because they characterize the ancient dis[illegible] of Siluria in Wales and on the borders of England. We have therefore in this Niagara district a country composed of the most ancient rocks yet discovered in the Earth's crust, and yet rich in organic remains. I have here a map of the district between Lake Ontario and Lake Erie. You see represented the Protean group, as it has been named by Mr. Vanuxem, and above that is a bed of soft shales some eighty feet in thickness, and upon the top of that is the Niagara lime-stone. That lime-stone extends for seven miles from its termination in the escarpment to a point near the rapids. The River Niagara flows out of Lake Erie in a tranquil, lake-like state, and runs gently along all the way by Grand Island, being on a level with Lower Canada on one side and New-York on the other. So nearly level is it that were the river to rise thirty feet, a considerable district of country on its border would be under water. From Lake Erie to the rapids—a distance of sixteen miles—the fall of the river, I believe, is not more than twenty feet; so that it quite resembles the expansion of an arm of Lake Erie. The hight of Lake Erie above the level of the sea is 565 feet; its hight above Lake Ontario is 334 feet. This fall is divided first into the fall of twenty feet in the sixteen miles from Lake Erie to the rapids; then comes a fall of forty feet in half a mile at the rapids; at the Falls it plunges at once 164 feet; then, between the base of the Falls and Lewiston, a distance of seven miles, it rushes rapidly along and falls 101 feet. It is evident that all attempts at representing the beauty and grandeur of this scene by any drawing must be perfectly unavailing. I have endeavored in this sketch to give you a notion merely of the geological situation of the country. It will of course seem to those acquainted with it most inadequate and in false proportion; but it must be remembered that it is a bird's eye view—such as you would actually get if you wore raised above it in a balloon. The first idea of this drawing was suggested by Mr. BAKEWELL, son of the eminent English geologist of that name, who visited the falls ten or twelve years ago. He published his drawing in the Gentleman's Magazine. On my arrival in this country I considered in what manner I could introduce into his view the geological structure of the country: and being able to make myself master of the rocks in that region, by having Mr. HALL, one of the State Geologists, for a travelling companion, sooner than I could otherwise have done, I prepared such a one, which has been copied, as you now see it by Mr. Russel Smith of Philadelphia—who, though unacquainted with the country, entered so completely into the conception that he has given an excellent representation of its prominent geological features.

Three miles below the Fall is the Whirlpool; and just below that is a deep ravine, called the Bloody Run, from an Indian fight which occurred there; there is also another ravine some ten miles below, of which I shall have occasion to speak. The first feature which strikes you in this region is the Escarpment, or line of inland cliff, one of which runs to a great distance East from Queenstown.—On the Canadian side it has a hight of more than 300 feet. The other is found at the junction of the Black Rock of Buffalo with the shales—and gypseous marls, as they are called. I shall not stop to describe mineralogically these various groups. They are sets of soft marls which contain gypsum and so much salt that they are often called saliferous gypsums.

The first question that occurs when we consider the nature of the country is, how the cliffs were produced: why do we so suddenly step from this range to the gypseous marls and then as suddenly to the subjacent shale and sandstone. We have similar lines of escarpment in all countries, especially where the rock is limestone; and they are considered to be ancient sea cliffs which have become more gentle in their slope as the country has emerged from the ocean. If we examine what is now going on on the sea-side, and reflect what would happen if the sea cliffs should be raised up as the country around was gradually raised (for I trust you are now familiar with this notion of upheaval) you will readily see how these escarpments are formed. There are similar appearances at Boulogne, in France, where we have alternate beds of limestone and clay, and between the base of the cliff and the present sea shore, (for the sea has evidently retired half a mile,) we see the edges of the strata *cropping* out between high and low water mark. Fifty years ago this cliff was 3000 feet high, as we see from its present position. I have myself seen frigates floating in places where we know historically that land existed but a few years since. The waves have beaten against the base of the rock, and broken off fragments which have fallen down and been swept away by the tide in the shape of mud and pebbles, until a whole yard of the coast has given way in a single year. In the course of time a considerable part of the rock is swept away. The shale and sandstone would thus be swept away, and the formation of the inland cliffs would be easily accounted for.

You may perhaps ask if the Ontario may not once have stood at a higher level and the cliffs have been produced by its action instead of that of the ocean. Some of you may have rode along the Ridge-road—as it is called—that remarkable bank of sand which exists parallel, or nearly so, to the present borders of Lake Ontario, at a considerable hight above it. I pefectly agree with the general opinion respecting this: that it was the ancient boundary of Lake Ontario. In some parts of it fresh water shells have been found. You cannot explain the escarpement by the aid of the action of the lake, for it extends farther and not in the same direction. It may be traced to the Hudson River and is not peculiar to any locality; but may be traced in all parts of the globe. When the land emerged gradually from the sea, as it is now doing, the sea would naturally create these sea-cliffs and during the upheaval they would of course become inland. In Europe proofs that limestone rocks have been washed away are abundant. In Greece in the Morea this is especially conspicuous. We have there three limestones one above the other at various distances above the sea. Along the line you may see literal caves—worn out by the action of the waves. In many of them are fragments of the limestone which have fallen down and are perforated by the *lithodomi*, and you can find among them shells of the *Strombus*, and various kinds of shells. The action of the salt spray which has also effected a sort of chemical decomposition, is also easily to be observed. So completely is this the case with each of these lines that you cannot doubt for an instant that here is a series of inland sea-cliffs; and this phenomenon being so certain in the Morea leads us by analogy to infer that these escarpements of the Niagara district were produced by a similar cause.

Other proofs of this denudation exist in the surface of every country and especially in the coal district of England. There in the coal field of Ashby de la Zouch in Leicestershire you see coal-beds pushed up 500 feet higher on one side than they are on the other—or there has been a letting down of the other side. This is called by the miners a *fault*. You would expect to find a corresponding inequality in the surface; you would think you ought to find a line of hills 500 feet high; but there is none. The whole mass has been carried away and the surface is as smooth and unbroken as in any other part of the country. In this way we can see that thousands of feet of earth must have been removed for an extent of twenty or thirty miles. When we examine the subterranean structure of the country we find proofs of such a denudation; and this it may be said has occurred in the Niagara District, either forcing up the cliffs or letting down the lower country between the base of the escarpment and Lake Ontario.—But an examination of the country will satisfy you that the cliffs could not have been thus produced. The rocks are continued on the other side. There are first the 150 feet of shale, then 25 feet of white limestone and then the grey and mottled limestone, giving three great divisions and a great number of subdivisions, in which the beds can be traced and described by their organic remains.—If these cliffs were produced by a *fault*, as in England the beds would not be found upon the opposite side.

But without dwelling longer on this denudation, I must pass to the more immediate subject of the present lecture. I have endeavored to show that these lines of escarpment were originally sea-cliffs, formed when the district was gradually emerging from the ocean. It is not disputed that there is some change going on at the Falls even now.—There occurs, as we know, occasionally a falling down of fragments of rock, as may be seen in Goat Island. The shale at the bottom is destroyed in consequence of the action of the spray and frost—the limestone being thus undermined falls down—and it has been believed that in this way there has been a recession of fifty yards in about forty years; but this is now generally admitted to have been overstated. There is at least a probable recession of about one foot in a year; though part of the Fall may go back faster than this, yet if you regard the whole river even this will probably be something of an exaggeration. Our observations upon this point are necessarily imperfect; and when we reflect that fifty years ago the country was perfectly wild and inhabited by bears, wolves, and here and there a hunter, we shall think it surprising that we have any observations at all, even for such a period back. We have an account of the Falls, given in 1675 by Father HENNEPIN, a French Missionary, who gives an exaggerated description of them, and yet one which is tolerably correct. He published with his travels a plate representating the Fall; but it greatly exaggerated its hight compared with its width. He describes Goat Island just as it is found now. He estimates the hight of the Falls at double what it actually is, which, after all, remembering that he did not measure them is not so gross as might appear; and any one who has witnessed them will readily excuse him for having given way to a little exaggeration in attempting to describe the grandeur and magnificence of the scene, without the slightest intention to deceive.

As you will see by this copy of his picture he represents a cascade as falling from the Canada side across the other two. He says that between Lake Erie and Lake Ontario there is a vast and wonderful waterfall: after speaking of this he says that there is a *third cascade at the left* of the other two, falling from West to East—the others falling from South to North. He says in another place, 'I wished a hundred times some one had been with me who could describe the wonders of this frightful fall.' He several times alludes to the third cascade which he says was smaller than the other two. Now those, who consider that because Father HENNEPIN gave the hight of the Falls at 600 feet, small value is to be attached to his testimony respecting any part of the country, do him injustice. I think it perfectly evident that there must have been such a third cascade, falling from West to East, as that to which he alludes.

A Danish naturalist, in 1750, came to this country, and visited the Falls, of which he has also given us a description, which was published in the Gentleman's Magazine in 1751. He also gives a view of the Falls. In its general features his description agrees well with that of Father Hennepin.—He went seventy-three years after him, and there was *then no third cascade*. But the point where Father H. had put this cascade he has marked and says that 'that is the place where the water was *forced out of its direct course by a prodigious rock which turned the water and obliged it to fall across the falls.*' He goes on to say that only a few years before there had been a downfall of that rock, which was undoubtedly part of Table Rock—and after that the cascade ceased to flow. Now, it does not appear whether he had ever seen Hennepin's account or notes. He only mentions the fact that there had been a third cascade; and it is a striking confirmation of the general accuracy of Father Hennepin's description. We find these two observers, at an interval of seventy years apart, remarking on the very kind of chang which we now remark as having taken place within the last fifty years; an undermining of the rock, and a falling down of the limestone, and a consequent obliteration of the fall. Every one who has visited the Falls, on inquiring of the guides about the changes that have taken place, may have been told that the American Fall has become more rescent shaped than it was thirty years ago, when it was nearly straight. The centre has given way, and now there is an indentation of nearly thirty feet. The Horsehoe Fall, also, has been considerably altered. It is not of so regular a rescent shape as formerly, but has a more jagged outline—especially near Goat Island; it has less of the Horseshoe-shape, from which it derives its name, than when it was given.

It is quite evident that things there are not stationary, and the great question is, whether by this action the whole fall has been produced in this manner. I have visited this year the Falls of the Genesee both at Portage and Rochester, and obtained many facts, especially at the upper fall, of this recession on a small scale. I made like observations at Le Roy, at Jacock's Run near Geneseo and in other places where it is impossible to go far back; for there time immemorial is only about ten years. But the people there will tell you there has been a change of a few feet or yards within this time. Mr. Hall observed a recession of several feet since he surveyed the same district a few years before. It is highly probable, therefore, that there has been an action of this sort constantly going on.

From representations made by other travellers I was desirous of ascertaining whether fresh water remains were found on Goat Island as had been said: for it would be striking if on this Island there should be in a stratum of twenty-five feet of sand and loam, pebbles and fresh water shells. They were found there and I made a collection of several species of shells found on the Island; among them were the *Planorbis*, a small *Valvata* and several other kinds. They were of genera found living either in the rapids, in the river above or in the Lake.

In digging a mill-race there only a few years since, there were found a great number of shells, and also the tooth of a Mastodon, some twelve or thirteen feet below the surface. It was the common Ohio Mastodon, and must have been buric beneath these twelve or thirteen feet of fresh water deposits—one layer at a time, each containing different shells. In answer to my question, whether similar shells were ever found lower down, the guide said he would take me to a place half a mile below, where the strata had been laid open. We found there deposited in the rock a small quantity of fresh water shells, showing that this old deposition extended down to that distance. Here we have proof that the river once stood at a higher level and in a tranquil state; and there is every appearance of the rock having been like a solid barrier to hold the waters back in a lake-like state, so that they might throw down these fresh water deposites at that hight. You will understand this better if you consider that if the Falls go on receding, no matter at what rate—an inch, a foot, a yard in a year—in the course of time the whole must recede considerably from its present condition. What proofs should we have of this afterwards? You will easily see that if the river should cut its way back to a certain point, the effect would be to remove the rocky barrier, the limestone of the rapids, which had been sufficient to pond the river back. But if the river cuts its way back, this barrier could no longer exist; the channel would be deepened, and the deposites existing high and dry upon the land would become proof of the recession. This kind of proof we have that the Falls have receded three miles from the whirlpool, the limestone having been higher at the whirlpool than the river at the Falls. It may be well to say that the beds all dip to the south, at a rate of about twenty-five feet in a mile. In seven miles the dip causes a general rise of the platform to the north, so that, when at the top of the cliff, you are at a greater hight than the level of Lake Erie; and if the Falls were formerly at Lewiston, their hight was probably nearly double what it now is. Mr. Hall suggested that at that time the whole fall was not at one place, and I think it quite likely that that was the case. There is reason to believe that one fall was upon the quartzose sand below, and the other on the Protean bed. The upper part would of course recede faster than the lower, because it is softer, as is seen to be the case at Rochester; but the limestone becoming thicker and harder would recede more slowly. There may have been several falls, as at Rochester—each one of them being less high than at present, and yet the whole being nearly double its present hight.

I told you that the river fell about 100 feet between the base of the Falls and Lewiston—so that the beds slope at that rate. This slope of the river and then the upward slope of the platform are the reasons why the falls now are of less hight than formerly. So when we carry ourselves back in imagination to the time when the river had not receded so far, we have a barrier of limestone much higher. The valley in which the river then flowed must have been much narrower than its present ravine. The distance now from the Canada to the American side is about three-quarters of a mile, whereas half a mile below it is only half that width. Further investigations by tracing the fresh water deposites lower will give more precise information.

You might suppose that, if we find the remains of a Mastodon in a fresh water deposite so lately laid dry as that near the village of Niagara and only twelve feet below the surface, the Mastodon had lived in the country at a modern period: you might think that perhaps a few centuries would have been sufficient for the accumulation of twelve feet of shelly sandstone and limestone and that it may have been recently that this Mastodon was buried when the barrier was at the whirlpool before this twelve feet of fluviatile strata were deposited. Yet these strata are older than the whirlpool.

Among the objections to the supposition that the ravine was cut out by the Niagara, one is that at the place called the Devil's Hole or the Bloody Run, the ravine must have been cut by some more powerful cause than by a slight stream. But this I regard as no objection at all; for on examining the nature of the soil, &c. I am convinced that even the small stream which now flows would have been perfectly competent to have cut out the ravine, and that we need look for no more powerful cause. Suppose the Falls once to have been near Lewiston: it would recede differently at different times—faster when the soft shales were at the base; at other times slowly when the hard sandstone was to be cut through. First of all came the quartzose sandstone for a certain distance; then the Falls receded slowly, but more rapidly when it came to the soft shales. Then comes the sandstone again at the base which now extends to the whirlpool, and here the movement was slow. It probably stood for ages at the whirlpool. Then for another period it receded more rapidly; and it is probable that for the last mile its recession has been comparatively slow, because the Protean group and about twenty feet of sandstone, making about fifty feet of hard rock at the base, were to be cut through. It is certain that the movement now is at a faster rate, as the shale is exposed. If it recedes one foot in a year, then in about five thousand years it would recede a mile; and as the upward slope of the bed of the river is about fifteen feet in a mile, and as the bed's dip to the south is about twenty-five feet in a mile, we must have about forty feet for the loss in hight of the Falls by the receding of one mile. Another 5,000 years would cause the loss of another forty feet, and then eighty feet would have disappeared and the cataract would fall over a solid mass of limestone only eighty feet high. Thus, at the end of 10,000 years, when the Falls shall have receded two miles, they would be eighty feet high. The recession then would be extremely slow, as the base would be of solid limestone.

But all these calculations would be easily vitiated by disturbing causes. Thus by interfering with the body of water above the fall—by carrying them away, as is now done by the Erie Canal and the Welland Canal in Canada we should have a different state of affairs. All the water taken from the upper lakes, as by the Illinois canal, &c. cheats the Niagara of its waters and acts as a disturbing force. Every mill race built above the falls has the same effect: and though this may seem to be a trifling matter, still in the progress of population and civilization such things may be frequently perpetrated and thus, in the end have a serious influence.

It has been estimated that about 15,000,000 of cubic feet fall over the cataract in every minute: this was ascertained by an engineer under the direction of Mr. RUGGLES. By all the causes I have mentioned, perhaps one four-hundredth part of this may be diverted into other directions; and this is certainly an appreciable quantity, and might have no inconsiderable effect in the progress of the recession. I only mention this as one of the disturbing causes which may vitiate all the calculations of which I spoke. The movement of the whole country which I have before alluded to may be another cause of disturbance. It is extremely probable that during the period when the Falls were receding from the whirlpool there may have been an upward, or downward, or perhaps an oscillating movement of the whole country. This would leave whole cliffs exposed, as has been done in other localities in the St. Lawrence, of which you have here a representation—where columns of limestone are standing, perforated at different hights by the lithodomi. The same motion may have extended to the great lakes and have affected this whole section of country. You will see, therefore, what a variety of different causes we have to regard in making any estimate of the former state of this District.

LECTURE VIII.

BOULDERS AND ICEBERGS.

The subject of which I shall treat to-night is what we term the *Boulder Formation*, or sometimes the Norfolk Drift. The term boulder is applied to any large mass found resting upon the superficial gravel brought from a distance. By some, chiefly the writers of the last forty years, this formation is called diluvial; because they believe that this superficial gravel, and sand, and mud, in which are found these rounded fragments of rock, have been brought thither by a rush of some mighty deluge, either at one time or at different periods. But those who have thought that they saw reason to refer a large part of this to other causes prefer the term *Drift*—as not choosing to commit themselves to any particular theory except that which is certainly known to be true, that these boulders have been *drifted*, by some means or other, to a considerable distance from the parent rocks, from which, as fragments, they have been torn. You have so many examples in this country, of these foreign rocks scattered through beds of sand and mud, that it is not necessary for me to enter upon the description of any particular localities in Europe. If you pass by the great excavations that have been made for streets in Brooklyn, you may see some forty or fifty feet in thickness of what we call rubbish, an unstratified, confused mass of clay and sand, containing fragments of rock of various kinds. This may be seen near the Navy Yard, and in all parts of the suburbs of the city. The same kind of formation may be seen in various parts of the North of Europe, as well as in different districts of this Continent. In Europe, it is particularly noticeable in the country bordering the Baltic, beginning with Finland, and through part of Russia and Poland, to Pomerania, Prussia, and Denmark, through the lower part of Sweden. The whole country consists of land at a moderate elevation, covered, to depths that have never been pierced, with this boulder formation, sometimes a thousand feet thick, and often, indeed, still more. It contains no strata; and you would become sensible, after having made a geological survey, how very rare are unstratified rocks which are not crystalline, like granite. Sometimes we find the boulder formation, entirely unstratified, passing into another strata which is arranged in layers. The absence of fossils—of organic remains—is another characteristic which makes it difficult to decide the nature or origin of this formation;—whether it be fresh-water, formed in lakes, or a marine formation, formed in the sea—is a matter of great doubt from the absence of all organic remains. Sometimes, indeed, we have found shells and bones washed out of the older rocks; for, relatively speaking, this is a modern deposite—being strowed over other strata containing fragments of them all, and occasionally of their imbedded fossils. Sometimes, too, we find them alternately of stratified and unstratified rocks.

In tracing along this remarkable deposite through the borders of the Baltic, we sometimes find fragments of rock which must have traveled hundreds of miles from their point of departure, and, as a general thing, we shall find that they grow larger in size as we approach the region from which they were derived. This I found to be the fact in going north from the margin of the Rhine to Holstein, and Denmark, where I found fragments of Scandinavian rocks, in Sweden nine and sometimes forty feet in diameter; and at last the whole country was made up of these rocks. Thus by tracing the stream along, we shall find that as it diminishes in size the stones continually diminish in their individual dimensions. This may be seen any where between the Thames and the Tine, and by following it out in any region you will become convinced that there has been a general drift from the north. You may travel for eight or nine hundred miles over the plains of Russia, and you will find these *Erratics*, as they are called, associated to such an extent with the rocks in the neighborhood, or immediately subjacent, that they have acquired the color and mineralogical character of the rocks of each country. If, for example, you trace the boulders to the red sandstone of New Jersey, you will find them red. So at Brooklyn, you will find that in great part they are red. Yet here in the red base you find scattered fragments of the trap of the Palisades, huge masses of granite from the Highlands, and some of the green serpentine of Hoboken, all mixed together, and yet the whole reddened by the colors and marked by the character, of the adjoining sandstone. So in Europe, the boulders are white in the chalk of Scandinavia; black in the carboniferous formation near Edinburgh, where the bituminous shale of the coal formation enters largely into their composition. Sometimes you find them entirely angular, as if they had not suffered any of that mechanical rubbing against adjoining rocks, or against each other, which has perfectly rounded other masses equally large. Some of these are so large that it is difficult to imagine that any force of water, which is the agent usually assigned, could be sufficient to roll them over and over as is necessary. Take some of the gneiss for instance: the edges of some huge masses have been cut off, so that the whole is as perfectly rounded as any of the smaller pebbles. Oftentimes, too, these large boulders have been carried across seas—as from the Scandinavian rocks to the south side of the Baltic. We have them too, perched upon the Jura peaks, having evidently been carried from the higher Alps over a valley fifty miles wide, and deposited upon fossiliferous limestone rocks, which have nothing in common with those of the Alps. This is the kind of appearance which has so perplexed Geologists, and to explain which, shall be one purpose of this evening's lecture.

I will first, however, allude to one other appearance which distinguishes the boulder formation.—When it rests upon hard rocks—rocks which are capable of taking and retaining a polish—rocks which have not wasted away by disintegration—we find, upon removing the sand, &c. the solid rock below sometimes polished so as almost to answer the purpose of a looking-glass; at other times we find it scratched and ridged with long parallel stripes, perfectly straight for hundreds of yards, and sometimes for a quarter of a mile, occasionally deviating from being parallel to each other, but still retaining the same general direction from north to south, or sometimes 20 or 25 degrees towards the east or west of that direction. This is evidently a common characteristic of these erratics; and any theory advanced to explain them must comprehend that appearance.

Another grand fact which is now established respecting their geographical distribution is, that they are found in the Northern Hemisphere, both in Europe and this country, extending from the poles, and they diminish in quantity as they approach the warmer and equatorial regions, and at length disappear when we come near the tropics. We find them in Europe from the north of Sweden and Norway to the coast of England, in latitude 50°. We find them here still farther south, but the Long Island deposite is one of the last grand deposites, and that on the Susquehanna is, I believe, the most southerly; and in traveling toward Georgia, or even on the James river and the Potomac, you will be struck with the absence of these large erratic fragments. It is the same in Russia, in travelling from north to south; and it is only when there is a chain of mountains like the Alps, in latitude 46°, that any exception is observed. From these mountains, as from the Jura chain, these boulders seem to radiate as from a centre. You may see them traveled to Lombardy and toward the Italian side. Even in the Grampian mountains of Scotland, you may see them scattered over the hills on every side; so also with the small Cumberland chain. Thus, mountain chains seem to have exerted the same kind of influence as the poles; for this general theory is found to be true, not only of the north pole, but also of the south. When you pass from the southern part of the United States through Mexico to Peru, at Quito you find no boulders, except at the foot of some mountain chain, where we may easily suppose the melted snow and other causes sufficiently obvious, account for their presence. Passing to Chili, it is not till you reach latitude 41° that you begin again to meet these boulders, and then they continue to increase to Terra del Fuego, where they are as magnificent in their developement as in New England or in Sweden.

Another very remarkable appearance in regard to the stratification of this formation, is the contortion and disturbance of some of the beds. In parts of the strata in Scotland, for example, you find masses of the unstratified boulder with pebbles below of various kinds, as fragments of granite, gneiss, &c, in which parts shall be twisted so that a vertical section would pass through the same bed three times. You find alternate layers, first pebbles of a particular kind and color; then sand, then loam, and then gravel—all loose, but so that you may trace the same bed for several yards, one layer being deposited above another in a nearly horizontal position; and we find them sometimes folded together—bent back upon themselves. This appearance was of a most perplexing kind, and evidently implied a lateral thrust by which the pliant beds were brought into the folded position, though those below had suffered no disturbance.

In some cases we have a mass of chalk resting on another bed, in which one has been pushed out of its original position, and the gravel and sand folded around it. In other cases, as in part of the northern coast of England, for twenty miles this unstratified *till*, as it is locally called in Scotland, is covered with a layer of horizontal loam in which are curved strata. This folding and bending of the beds in a circle sometimes, has been effected, and the horizontal layers below are not at all disturbed; so that it cannot be a motion from below which has caused it—a subterranean upheaval or subsidence, which I have before explained, caused by volcanic action, by which we explain mountain chains, &c. This cannot be introduced here, because in that case the lower beds would have been disturbed as much as the higher. This may be seen in the section laid open in Brooklyn; none of the contortions there have been so violent as some on the Norfolk coast of England and Scotland; but the same general disturbance may be observed.

As to the age of these boulders, you find them both here and in Europe, standing over rocks all of the most modern tertiary strata. I had an opportunity in Sweden of showing how modern some of the erratics are, by finding fragments of gneiss sixteen feet in diameter, resting upon a layer of sand; then came a bed of blue marl, containing an immense number of shells of the eatable muscle, from which the blue color of the marl is derived. That muscle is now a living species in the Baltic, and is found at Upsala, near the ancient University.—Several other shells are also found peculiar to the Baltic. The water of the Baltic contains only one-fourth part as much salt as the water of the ocean; and the shells found in its brackish waters, though not of different species from those of the ocean, are yet of a dwarfish form, and of a different shape from those that live in the sea. There are also found freshwater shells, which have been brought down by rivers. We may observe, then, how very modern is the transportation of some of these blocks; for not only do we trace them to the times when those species existed the same as those which now live, but when they lived placed under those peculiar geographical relations which have modified the character of the waters.—

I do not say that they are all as modern as that, for some of them contain shells that are partly extinct, or at any rate which do not live in the same region. In the St. Lawrence Capt. BAYFIELD came across boulders containing a small assemblage of shells which he sent to me many years ago; and Dr. BECK, a Danish Geologist, observed that there were fauna more ancient than those from the Baltic, which I received at the same time. There was a small number of species peculiar to the Southern regions, and the same as are chiefly found in Greenland and other districts near the Pole, as if the country had formerly been colder and the boulders had been dropped down by icebergs; for Capt. BAYFIELD frequently saw immense rocks carried by icebergs and let down deposited with strata containing shells the same as those I spoke of in treating of the Niagara district. Thus we arrive at the conclusion that this boulder formation is one of the most modern deposites geologically considered—sometimes extremely modern, and in other points ascending a little higher, just to the period when the same shells existed, nearly all of them belonging to living species: the newer Pliocene period as I have before designated the era—when perhaps 90 out of the hundred shells found are of living species. Down to the latter part of this newer Pliocene period it appears that those erratics extend. We have to account then for this formation being of such vast thickness and unstratified; for rocks having been transferred hundreds of miles over lakes and valleys; for their being nearly non-fossiliferous; for their being found chiefly in the Arctic and Antarctic regions or near mountain chains; and to explain how they are so often found contorted and disturbed while the strata they overlie are still horizontal.

In the hope to explain the greater part of these phenomena, I propose first to treat of *Glaciers*, and then of *Icebergs*. You are aware that in lofty mountains, especially in the high latitudes, the snow never disappears during the whole year.—There is constantly falling snow which the summer heat is never sufficient to melt; and in Switzerland where the Alps are three miles in hight above the level of the sea, although in latitude 46°, their peaks are covered with perpetual snow; which comes down and fills the valley for ten or fifteen miles: then this ice becomes consolidated, being melted during the day and frozen in the night—so that it is pushed down towards the valley to a point 3000 feet above the level, where the heat becomes so great as to arrest its progress, and it melts, and gives rise oftentimes to a considerable stream of water. The cause of the motion of these glaciers has been a matter of considerable controversy. Gravity is admitted on all hands to be one considerable cause. It is suggested by SAUSSURE, and by the earlier writers is believed to be the principal cause; but this is denied by M. AGASSIZ in the history of his late exploration of the Alps.—That this snow, if it goes on accumulating upon the mountains which are so steep, will by its own gravity fall down, is unquestionable. You see this to be the case in *avalanches*, as they called—sliding own of large masses of snow in warm weather, which continues until the valley is choked by this descending mass, which crushes the trees and vegetation that lie in its path. These become of such enormous size that they are sometimes 100 or 200 feet thick, and in particular places 500 or 600, though it is supposed now that 120 or 180 feet expresses their average depth. In Switzerland, where the glaciers of the Arve, the Lauter Arve, and the Shrecken meet, the former being merged in the other, along the middle is a remarkable ridge of rocks—many of them angular and some rounded. Now the first question is, how came these blocks in the middle of the valley where it is two or three miles wide. The glaciers descend from the region of perpetual snow to a hight of, say 8000 feet above the level of the sea. How came all these rocks in the middle? You might imagine that from the steep sides there would be fragments detached.—Avalanches might cause this, or frost penetrating the rents and freezing the water, would occasionally force them out and cause the rocks to descend. Sometimes lightning strikes the Alpine peaks, and shivers off large masses of rocks which descend. So that we should not be puzzled to find along the base of lofty cliffs two, three or four thousand feet high, these fragments of rock. This would be perfectly intelligible. But how should they get into the middle of the valley, and why are there five distinct parallel ridges of these stones? SAUSSURE was at first completely baffled in accounting for this. But having once found the explanation, it was so easy that it became surprising how it could have been missed.

Prof. AGASSIZ found in exploring the higher regions that this was a *necessary consequence* of the junction of the two glaciers. It is easy to see why these lateral *moraines*, as they are called, should exist—the rocky fragments being deposited along these glaciers by their rubbing against the sides of the mountains. But suppose one of these immense masses of ice to be descending the valley of the Arve; and here comes a tributary to join it from the Lauter Arve—the rocks instead of being deposited in lateral moraines by rubbing against the mountain sides will be brought into the middle of these two united frozen rivers, thus forming a central or medial moraine. Now as the glacier moves along, (and in a hot day you may see the motion daily—although an inch, or perhaps half an inch an hour would be a rapid movement,)—you may see sometimes fragments falling down—rubbing one against the other, and great rents often traverse the ice with a noise like thunder. By this rubbing against the sides of the mountain the rocks become rounded. Many of the fragments fall through the fissures to the bottom, and some are caught in the middle—the fissure penetrating only twenty or thirty feet. Sometimes, however, they fall to the bottom, and then the ice resting upon them grinds them along the rock, which becomes polished—those at least capable of receiving a polish—and scratched and furrowed as we afterward find it. All this may be seen by the occasional melting back of the glacier. So at the termination of the glacier it presents a beautiful green arched cavern, out of which a torrent of water rushes down the valley. Frequently the glacier melts back from the extremity, and thus gives an opportunity to see what has taken place under it, and you will find the bottom oftentimes most beautifully polished. In some of the boulders you will find quartz pebbles, and these have scratched and made furrows upon the limestone and other rock along which they have moved—just as a diamond scratches glass.—In other places you will find still deeper furrows nearly parallel to each other. You will also see—as I have had occasion to refer to the prodigious power of these ice masses—rocks that have been ground down to the finest impalpable powder; and nothing can exceed the fineness of this mud which is formed from the powder thus produced by these masses of ice one or two hundred feet thick, equal in weight to five and twenty or even fifty feet of solid rock.

The downward motion of the glaciers is partly due to gravity. But Prof. AGASSIZ says that still more is due to the alternate melting and freezing of the water. The ice is in fact a great sponge and not only may you see water in the day time held up in the clefts—as many of you who have traveled in Switzerland can testify—but the whole surface is a spongy mass which imbibes the water during the day, which every night is frozen by the same frosts, and thus occurs a universal dilatation of the whole mass; the water in all the rents freezing causes an expansion, and as this cannot push aside the mountains on the flanks, the only vent for the force is downward—in which direction it has the effect to force the huge mass down at the rate of one, two, three or four inches an hour, according to the heat of the summer and the amount of alternate melting and freezing that goes on, and also according to the farther distance which the glaciers have reached. I may mention that every one of the moraines between the central one and the sides is produced just like the large one—by the junction of the tributaries which come one after another down for many miles. Thus the diffent moraines may be traced—one to the Schrecken and others to various tributaries which join higher up. Those at the sides move faster than the central ones—because the reflection of the heat from the boundary rocks is in addition to the direct heat of the Sun, causing the ice to melt away faster: and thus the ice is drawn from the middle to the sides and the moraines become more and more scattered. At last we have only one great lateral moraine with smaller medial ones, and when we behold the beautiful arch at the termination we shall find in the middle of it no fragments at all. There was some difficulty in accounting for this, because it was supposed that the fragments had been caught in the fissures. But why should the extremity be so beautifully free from them? The answer is this: that when a block falls into a fissure it works its way up—not by rising against gravity—but in this way: as the glacier goes down, it continually diminishes at the surface—the upper surface melting away; and the block which had dropped down to a certain distance must continually get nearer the surface. There too this block protects the ice from the rays of the Sun, and you see the mass below unmelted. If the pebble be small it soon becomes heated through, and thus forms a pool or hollow. Thus if the rock be small, we shall have a hollow; if large, the opposite—or the rock will be mounted up on a pedestal. The wind also is one cause of evaporation. The ice wastes away like camphor, without passing through the liquid form.—The general waste of superficial ice tends to bring up the fallen mass toward the surface.

I have said that there was great difficulty in seeing how such large fragments could be so perfectly rounded. Sometimes we have masses perfectly angular—twenty feet in one direction, and twelve or fifteen in the other. There is one, well known to travelers, in the central moraine of the glacier of the Arve. It was here that a hut was built in which a family lived in the summer. The rocks are rounded here, as is said by some, not by the action of the ice, but of the river that flows beneath the ice. But Professor AGASSIZ says that, as a proof that it is the ice, and not the river, to which the rounding of the rocks is attributable, you may go up to points above where any stream commences, and still you will find that the motion of the ice above has rounded masses of all sizes. This is found so far above the line of perpetual snow that it cannot be attributed to the action of running water.

I mentioned a hut, built by Professor HUGE, some time ago. There are some remarkable observations concerning it, which show the rate of motion in these glaciers. It was built in 1827, on the glacier of the Arve. When Professor H. went back nine years after in 1836, he found that the hut had gone down, without being otherwise disturbed or injured, 2200 feet. He went again four years after, and found that it had gone down at twice the same rate. Taking an average of the whole for the thirteen years, it was found that it had gone down at the rate of eight inches in twenty-four hours. In the first part of the distance it went eight, and in the second sixteen; and the motion was entirely in the summer. In the winter, this glacier stationary, showing again, as Professor AGASSIZ remarked, that the motion was chiefly owing to dilatation—to this alternate melting and freezing. This is certainly a strong argument in favor of that theory, that it is chiefly during this congelation and melting that the chief motion is observed.

There have been periods when the glaciers made less advance than at others, as between the eleventh and fifteenth centuries; and again in the seventeenth and eighteenth a general motion forward occurred. This period of retrocession and advance is a striking meterological phenomena showing the cycles of climate. When there is a great fall of snow during the winter, which melts in summer, there is an advance.

In Chili, which has the same latitude as the Alps in Switzerland, we have glaciers descending to the sea; but at the Alps they only descend within 3000 feet of the sea level, and this too, although the Andes are only 7000 feet high—half the hight of the Alps in the same latitude. The reason of this singular phenomenon is that to which I have alluded—that the summer heat is less intense in the Alps. In Europe we have to go to latitude 67° before we find a single glacier reaching the sea.—But in the Southern Hemisphere, in latitude 46°—in Chili—we find this occurring twenty-one degrees nearer the equator; so that there is here an actual generation of icebergs in a region which is almost the limit to which the floating icebergs reach. That alternate period of advance and retrocession among the Swiss glaciers is one of the most remarkable facts, and explains many geological phenomena. In observing the terminal moraines of the Alpine glaciers we often find a huge mass left at the end of one summer. Then when the glacier advances again it pushes forward the moraine of the last year into that of the year before, and that into the third, and so on until we have four or five together, forming a hugo mountain.—You may seo many of these ancient moraines covered with houses, and lofty trees, and various kinds of herbage; and as I witnessed in 1838, when the glacier was advancing, if it approach this ancient moraino it destroys the forests upon it, forcing in the walls of the houses and crushing them by a a slow and almost imperceptible, but, at the same time irresistible, power; and after treading down these lofty trees for a series of years, it will again retreat; and then the wood will grow again, the inhabitants again build their houses, and forget the disaster which once rendered them desolate. So that the trees show by their ago how it has been sinco the ice visited that part of the country.

These phenomena have been well described by M. CHARPENTIER, who remarked that we always have an unstratified mass of large boulders in the same district, the angular and rounded being mingled together. This shows that they cannot be attributed to any action of water, for water exerts an assorting power carrying the finer materials farther than the coarser, and would carry tho small stones to farther points than the large ones. Each different size would, supposing the whole to be attributed to the action of water, be arranged in different layers. But ice would carry them all indifferently to the samo place, and we should find them unstratified—a promiscuous, confused mass, and that is the character of all tho moraines. Now we are not to jump to the conclusion that all the boulders of Long Island are attributable to glaciers. I believo that they are not, but still to the action of ice. The pebbles found at North Haven and along the Connecticut valley, in the boulder formation are rounded on three sides but flat on the other—resting on polished rock; and all the furrows are parallel over a large extent of country. This parallelism does not bespeak the action of water; for in that case there would be none of the scooping out that we see in the action of glaciers; the motion would not be always in the same direction; but if the fragment of a rock becomes frozen in, it is kept in one position, and we should have therefore straight parallel grooves.

But not to dwell longer on the action of mere glaciers, let us pass to the consideration of icebergs. We know that icebergs carry fragments of rock in the samo way as glaciers; that is, fragments of rock rest on glaciers when they come to the sea, and are then conveyed away by tho floating iceberg, as well as by the moving glacier on land. This has been observed even in latitude 46° in Chili. SCORESBY tells us that he met in lat. 69° an iceberg in the Atlantic with 100,000 tons of rock upon it. But in 1839 there was met in the South Atlantic an iceberg 1,300 miles from any known land, from which projected a block twelve feet thick: how much rock was buried beneath the surface was not known. I do not say that this was 1,300 miles from any land—but only from any *known* land. Now as this was floating at a considerable rate from South to North—as it melted the rock would fall to the bottom of the sea, and if the bed should be raised some day, wo should have boulders at an immense distance from their starting point. The shores of the Antarctic regions are thus covered with coast ice a mile or two in thickness—stranded ice containing great quantities of rocks. Thus as the glaciers descend to the sea, they float off, the rocks fall to the bottom, and the floor of the ocean is thus strewed over with them, and if the ice melt in still water tho formation would be unstratified, because all the rocks fall perpendicularly through the water. But if there were a current, then an assorting power would be exercised, and wo should have regular strata.

I now come to a remarkable feature to which I must allude, as I spoko of it at the beginning of my lecture, but of which I can only speak briefly. I mean the appearance of Alpine rocks on tho peaks of the Jura. The western valley is composed of talcose granite and gneiss. Then going farther East we come to the Bernese Alps, whero the mountains are composed of crystaline limestone, gneiss and other rocks, frequently of highly crystalino marble, fragments of gneiss, &c. Next are the Alps of the smaller cantons, Glaris, Schwytz, Uri, Zug, &c. Now the phenomenon alluded to is this. We have the great valley of Switzerland between the Jura and the Alps. The Alps are from 10,000 to 15,000 feet high, and the Jura only one-third as high. Now we have the same blocks in the plain below, in Lake Geneva and others, perched upon the Jura Mountains, at all hights and of all sizes—one in particular, celebrated under tho name of Pierre â Bot, near Neufchatel, no less than forty feet in diameter, composed of gneiss from the Alps. The wholo chain of the Jura is composed of fossiliferous limestone, entirely different from the Alpine rocks; so that we have no other resort than to suppose that these rocks must have originated in the Alps. All agree that those on the central part of tho Jura came from the Bernese Overland; then, again, tho block of slate of the Glaris region sent over its erratics to the Eastern Jura, near Basle, and those on the Western Jura have come from the region of Mont Blanc and the Valais.

SAUSSURE, VAN BUCH and other writers supposed that these phenomena were produced by some grand rush of waters in consequence of the rise of the Alps from the ocean; a most violent hypothesis contrary to facts now known. If we suppose that this was the cause of these rocks being carried across this great valley, how is it that they did not all fall down into the valley?—How is it possible that they should be whirled sometimes for several thousand feet? This has never been explained to the satisfaction of any one; though to be sure this is rather more satisfactory than no hypothesis. But the remarkable fact is that we have on parts of the Jura fragments of rock such as we must suppose glaciers must have carried straight across the valley fifty miles wide; so that the western stream seems to have followed the course of the Rhone, the Central that of the Arve and the eastern that of the Reuss and the Limmat. But to suppose all this is in defiance of all analogy of the motion of glaciers; for we must remember that they could have an inclination from one bank to the other of only two degrees; so that we should have them moving along a dead flat, which is contrary to all the laws of glaciers, that they should walk across this level and lodge these blocks upon the Jura peaks. I should rather believe this however than that they are owing to a diluvial rush, which is utterly inconsistent with all the laws of the transportation of matter.

There is another hypothesis suggested by the occurrence of glaciers in Chili in the same latitude as the Swiss Alps. We may suppose from geological changes, known to be going on in the upheaval of the land, &c., that the Alps were less lofty than they now are, during the boulder formation, and the Jura also. The sea may then have covered the bottom of that deep valley and the Alps—at one half their present hight—would have stood as high as the Chilian Andes. Suppose they sent down glaciers to the sea, as we know they do in South America, where Sir GEORGE AYRES has seen them with blocks of syenite and granite. These might be stranded in the great valley, which, in that case, would represent the channel that now separates the island of Chiloe from the main land. The island of Chiloe is about 100 miles long, and may well represent the Jura Chain. The Andes represent the Alps, and the channel the intervening valley. The Alps at half their present hight, would be sufficient to give rise to glaciers, which, descending to the sea, would become icebergs and float blocks across the channel. In point of fact there are found on the island of Chiloe blocks of syenite in one part and of granite in another, which might have been carried from different points of the sides opposite. Now if an upheaval were to take place on the Chili Coast, which should lift up the Andes—dry up the intervening channel—and lift up Chiloe so that it would appear to be a chain of mountains we should have the same puzzling appearance to future geologists. It would be wondered how these blocks of granite and syenite could have crossed the valley from the Andes and perched themselves on the Chilian Mountains. This hypothesis is infinitely more satisfactory than the one which attributes the phenomena to the extension of glaciers from the Alps to the Jura, or to the diluvial rush of SAUSSURE. There have been found also moraines on the Jura which have polished and scratched the surface—implying that formerly there were glaciers here also. This may have happened when the climate more resembled that of Chili.

I will now state one more fact of some interest here. I observe that Mr. MATHER, the State Geologist, to whom was committed the investigation of this part of the country, says that on the Eastern extremity of Long Island are blocks that have come from the neighborhood of the Palisades or from different parts of the Highlands. Traveling farther on he saw another group which came from the Connecticut region opposite; then to trap, porphory and other rocks from New Haven. Still farther were Rhode Island rocks and so in different parts were groups corresponding with strata opposite. In these cases we have not to call in the action of glaciers nor of icebergs to explain this. It may have been caused by the action of coast ice. Ice might float thither carrying these blocks and being stranded lodge its load; then the next year might come a little more. Capt. BAYFIELD after fixing the position of one block found it carried away several yards. The experience of DEASE and SIMPSON shows the immense power of these icebergs. The Utica, too, which has just arrived talks of icebergs in this latitude, 400 feet high above the water and as there are eight cubic feet below for one above the surface, we may judge of the enormous size of these icebergs which were several miles in circumference. They grate along the bottom of the ocean, ploughing up mud and sand, with a force sufficient easily to move a building like this, or even the whole city of New-York before them! This is the kind of action that produced those contortions of which I have spoken.

The top of a sand-bank in the bottom of the sea has been exposed to a violent thrust of this kind and while the strata below remained horizontal, those above would be forced back and folded over upon themselves.

I will now leave this subject half-told, as I have been obliged to leave so many others of equal importance; and still more at which I have not been able even to glance. In concluding I may take this opportunity—as this is the last lecture I shall have the pleasure of delivering in the United States before my return to Europe, being about to resume my geological tour and to visit various parts of the West and of Canada—not only of thanking you for the great attention you have been so kind as to show me but also to acknowledge the welcome which has attended me throughout my tour from Lake Erie to the Savannah river; and which has made me in this country feel as much at home as though I were in England; and I assure you that I shall always look back to the time spent here with a *home-feeling*, which will always make it difficult for me to regard America as a foreign land.

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