ELEMENTS OF GEOLOGY,

WITH AN OUTLINE

OF THE

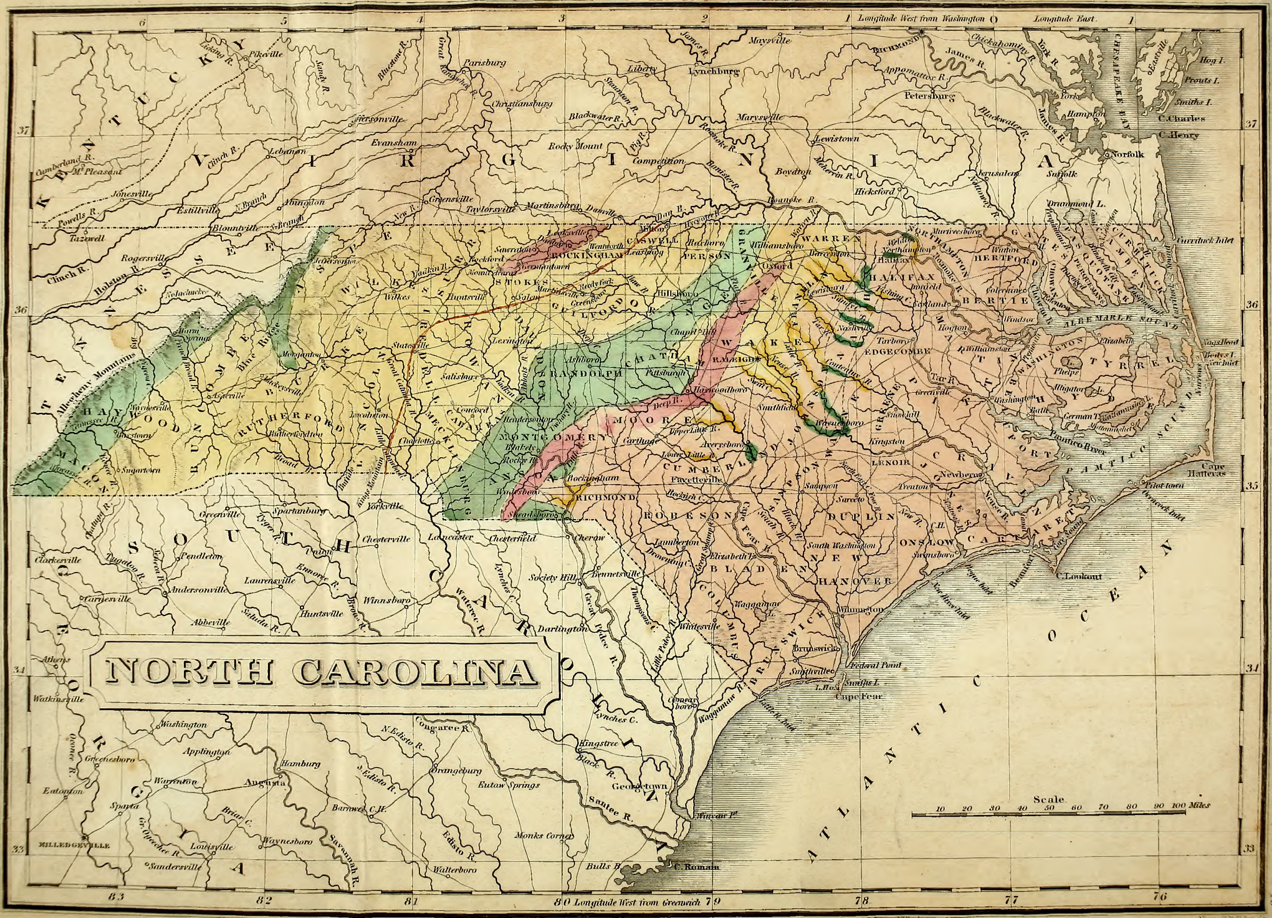
GEOLOGY OF NORTH CAROLINA:

FOR THE USE OF THE

STUDENTS OF THE UNIVERSITY.

BY ELISHA MITCHELL,
PROFESSOR OF CHEMISTRY, MINERALOGY AND GEOLOGY.
In the University of North Carolina.

1842.



NORTH CAROLINA
Longitude West from Washington
Longitude East
Longitude West from Greenwich
K E N T U C K Y
V I R G I N I A
T E N N E S S E E
S O U T H C A R O L I N A
G E O R G I A
A T L A N T I C O C E A N
Scale
10 20 30 40 50 60 70 80 90 100 Miles
CHESAPEAKE BAY
ALBEMARLE SOUND
PAMTICO SOUND
Pikeville
Parisburg
Christiansburg
Lynchburg
Maysville
RICHMOND
Petersburg
Norfolk
Suffolk
Hampton
York
C.Charles
C.Henry
Evansham
Rocky Mount
Competition
Marysville
Lewistown
Boydton
Hicksford
Jerusalem
Abingdon
Estillville
Blountville
Jonesville
Tazwell
Rogersville
Greensville
Martinsburg
Danville
Taylorsville
Drummond L.
Currituck Inlet
ROCKINGHAM
CASWELL
PERSON
WARREN
GRANVILLE
NORTHAMPTON
HERTFORD
GATES
HALIFAX
BERTIE
STOKES
GUILFORD
ORANGE
WAKE
FRANKLIN
NASH
EDGECOMBE
MARTIN
WASHINGTON
TYRREL
HYDE
BEAUFORT
PITT
GREENE
JOHNSTON
WAYNE
LENOIR
CRAVEN
CARTERET
ONSLOW
JONES
DUPLIN
SAMPSON
CUMBERLAND
ROBESON
BLADEN
NEW HANOVER
COLUMBUS
BRUNSWICK
MOORE
CHATHAM
RANDOLPH
MONTGOMERY
ANSON
RICHMOND
MECKLENBURG
CABARRUS
ROWAN
IREDELL
LINCOLN
RUTHERFORD
BUNCOMBE
HAYWOOD
MACON
WILKES
BURKE
SURRY
ASHE
Raleigh
Hillsboro
Oxford
Chapel Hill
Pittsburgh
Salisbury
Lexington
Statesville
Charlotte
Concord
Lincolnton
Morganton
Asheville
Waynesville
Rutherfordton
Wilkes
Huntsville
Germantown
Salem
Fayetteville
Haywoodboro
Smithfield
Waynesboro
Kingston
Newbern
Tarboro
Greenville
Washington
Williamston
Windsor
Edenton
Plymouth
Elizabeth
Halifax
Warrenton
Williamsboro
Wilmington
Brunswick
Smithville
Federal Point
Smiths I.
Cape Fear
Cape Hatteras
C.Lookout
Beaufort
Swansboro
South Washington
Elizabeth T.
Lumberton
Rockingham
Wadesboro
Averysboro
Carthage
Sugartown
Allegheny Mountains
Blue Ridge
Deep R.
Neuse R.
Tar R.
Roanoke R.
Dan R.
Yadkin R.
Catawba R.
Cape Fear R.
New R.
Broad R.
Pamtico River
Yorkville
Chesterville
Lancaster
Chesterfield
Cheraw
Society Hill
Darlington
Bennetsville
Winnsboro
Spartanburg
Greenville
Pendleton
Andersonville
Laurensville
Abbeville
Huntsville
Kingstree
Georgetown
Conwayboro
Orangeburg
Eutaw Springs
Monks Corner
Walterboro
Barnwell C.H.
Hamburg
Augusta
Washington
Applington
Greenesboro
Warrenton
Eatonton
Sparta
Louisville
Waynesboro
Sandersville
MILLEDGEVILLE
Athens
Watkinsville
Clarkesville
Carnesville
Santee R.
Congaree R.
Savannah R.
C.Romain
Bulls B.
Winyaw B.

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PREFACE.

A Treatise of Astronomy, adapted to the wants of the student living upon one part of the earth's surface, may be used with equal advantage in all countries. The same sun and planets, and with some exceptions the same constellations, are seen in all the habitable regions of the globe. Every country of considerable extent, requires its own elementary treatise of Geology. For although the great doctrines of the science are every where the same, those proofs and illustrations will be most convincing and satisfactory, that are drawn from strata with which we have been long familiar, or which we may have an opportunity of examining for ourselves. A greater extension will also be given to the account of the rocks of a particular age, in one country than in another; to the secondary strata in the State of Tennessee; to the primitive and tertiary, in North Carolina.

The substance of the following treatise, has been read for some years to the senior class in the University, but this mode of acquiring a knowledge of the science not being satisfactory, the book has been printed for their use, and is as large and full, as in the time allotted to this subject, can be studied with much effect. As the successive lessons are illustrated in the lecture room, by the necessary plates and figures, none of these have been introduced; but as these elements may find a few readers beyond the college walls, a map, exhibiting the position and extent of the different rock formations of North Carolina has been attached. It is only when the cultivators of this science shall have been greatly multiplied, and there shall be men in all parts of the country prepared to traverse it in every direction, and verify every fact laid down by them, by repeated examinations, that the geology of the State will be minutely and accurately known.

CONTENTS.

OBJECTS AND METHODS OF

GEOLOGY.

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1. *Geology is the Science which treats of the composition and structure of the exterior crust of the earth; the changes that are now proceeding in it; its condition in the most ancient times; and the causes by which its existing form and the present distribution and position of the materials of which it is composed, have been produced.*

The great mass of the earth lying within the exterior crust is not neglected, but the knowledge we have of it is very limited. The objects and methods of this science are more fully explained in the two following sections.

2. The different parts of the earth's surface are unlike each other. Some countries are spread out into level plains, and others roughened with hills or studded with mountains, whose tops rise above the clouds. If we descend from its exterior form and moulding to the characters of the soil and the constitution of the rocks, we find them equally various and dissimilar. Widely extended regions are fertile almost throughout, whilst others are covered with sand, and doomed to remain in future what they have been from the earliest ages—waste and trackless deserst. Indostan and Arabia, advancing from the continent of Asia into the southern ocean, do not differ greatly in size, the former being by about one-fifth part the larger of the two: their latitude, and of course their climate, so far as that depends upon nearness to the sun, is about the same. Arabia yields a scanty subsistence to a population of ten millions, whilst the soil of Indostan sustains not less that twelve times that number. The sand hills and middle or back country of North Carolina, furnish an example nearer home. The mineral riches of the earth's crust are not less unequally and irregularly distributed, than the causes of productiveness and sterility. Limestone abounds in the state of Tennessee; only a few small beds of it have been observed in North Carolina. The mountains of Pennsylvania contain coal enough to supply the United States with fuel for ages. New England is nearly destitute of this valuable mineral. For several years, about the

close of the last century, the single province of Mexico yielded a larger amount of silver, than was drawn from all the other mines of the world. The surface of the earth is constantly subject to slight modifications and changes.

The object of one branch of this science, called Positive Geology by some authors, and Geognosy by others, is, to ascertain the different kinds of rock of which the exterior crust of the earth is made up ; their distribution and mutual relations or situations with respect to each other ; the circumstances under which we find the valuable minerals they contain, and the alterations of texture and position which they undergo from age to age.

These ends are accomplished by a careful observation of the common undulating surface of the soil and of the rocks it contains ; of the precipitous sides of hills and mountains ; of mines and other artificial excavations ; and of those points where the elements and subterranean forces are exerting their greatest activity.

3. A question arises whether the more remarkable and important of the peculiarities just noticed are coeval with the existence of the earth, or the result of changes it has undergone since its formation. Did the Creator in the beginning cover the plains of Arabia with sand, mingle in the soil of Indostan the elements of lasting fertility, and place in the mountains of Pennsylvania and Mexico the mineral treasures for which they are now explored ; or have all these and others, been collected into the situations in which we find them by causes that have operated in succeeding times ?

Ample evidence will be furnished as we proceed, that the beds of earth and rock forming the outer crust of the globe, and the valuable minerals they embosom, are of different ages, and have been deposited in succession. It will be sufficient for the present to refer to the remains of shell fish and other marine animals that lie imbedded in them, often on the tops of high mountains, and in regions remote from the sea.

Limestones composed of shells from the ridges of hills in Palestine. Those wonderful stones of the temple at Jerusalem, to which the disciples called the attention of Jesus Christ when they drew from him a prediction of the impending ruin of that magnificence, abound in them ; and it is in rocks of this nature that the ancient Jewish sepulchres are excavated.* The pyramids of Egypt are both founded upon and built of a kind of oolite, full of small nummulites and other shells, once supposed to be petrified lentils and other seeds left by the workmen employed on those stupendous fabrics. In most of the countries of Europe, shells occur in greater or less abundance over extensive tracts ; the mountains of China, according to the Jesuits, are covered with them. Ramond observed them in the Pyrenees upon the summit

*Jamieson in the Edinburg Encyclopedia. The shells are probably not as abundant in the rocks about Jerusalem as he represents them. See *Silliman's Journal*, Vols. 9 and 10.

of Mount Perdu, 10,378 feet above the level of the sea; on the Andes they are seen at the height of nearly 16,000 feet, and around the sides of the Himmaleh mountains at a still greater elevation. In the United States they are of common occurrence, but generally at lower levels, as in the states of Kentucky and Tennessee, beneath the town of Wilmington and at other places in the low country of North Carolina. Petrified fishes and other marine animals are distributed, though more sparingly, throughout the surface of the globe.

These remains of living beings, of which not only the individual has perished, but the race has been for ages extinct, prove that the existence of the earth has not always been marked by the condition of tranquility and repose in which we now behold it. They render it probable that the globe itself has been agitated by violent convulsions, and certain that it has been subject to revolution and change. They did not escape the notice and attention of the ancients,* but they were regarded with the less interest, because they were held by many not to be real remains, but imitative forms, produced by a certain plastic and generative property residing in the earth, somewhat analogous to that which causes vegetables to spring up and grow. In succeeding times they were referred to a single catastrophe, (the deluge) to which we have the testimony of the sacred Scriptures, that the earth has been subjected. But it is now ascertained that this account of their origin is inadmissible. They are not merely scattered through the loose soil, but imbedded in the interior of solid rocks, occupying an extent of hundreds of square miles along the sides or on the tops of mountains, and hundreds of feet in thickness. Such vast masses could not have been collected and consolidated within the space of less than a year, that the waters of the deluge covered the earth. The genera and species occupying the different beds placed in succession one above another are also different, by which it is further proved that the causes by which the condition of the globe has been changed, and the materials for the creation of ranges of lofty mountains, prepared and elevated into their present positions, have in more than one instance been active.

The object of the second great branch of this science, sometimes denominated speculative or theoretical Geology, is—To discover, as far as possible, from the appearances presented by the rocks, beds of clay and sand, and the animal and vegetable remains that are imbedded in them, the nature of the causes by which they have been formed. It embraces therefore the primeval history of the earth, and an investigation of the number and kinds of the revolutions and changes to which it has been subjected, and the character of the agents by which they have been produced.

4. Positive Geology may be regarded as a branch of Natural

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* Vidi factas ex aæquore terras
Et procul a pelago conchæ jacuere marinæ.
Ovid Metamorph. Lib. xv. 263

History. Theoretical Geology, occupied in the investigation and discovery of causes from their effects, belongs to Natural Philosophy. But as many of the doctrines of the latter are derived from the characters presented by organic remains, the connexion between it and one department of Natural History is very intimate. It is of importance to the modern geologist that he be well versed in the science of conchology. Positive Geology, which ascertains the facts on which many of the conclusions of the other are founded and built, will demand our earliest attention; but in this science more than in most others, it is necessary to bring forward facts, points of theory, and historical details, by turns and in succession. Facts of first rate importance in the illustration of our theories, are without interest when their bearing upon the great doctrines of the science is not apparent, and not only have opinions once generally held, but now abandoned, left their impress upon the language it employs, but some acquaintance with them is necessay to a correct understanding of the works on Geology that are published in our own day, and of the views entertained by the philosophers of the present age.—A few general statements on the whole subject are first to be presented and some terms explained.

Astronomy, relating to bodies separated from us by an interval (with a single exception) of several millions of miles, is the most ancient, and Geology, having for its object the earth on which we live, one of the more recent of the sciences. Nor is this remarkable. The magnificence of the starry heavens drew to them the attention of the early inhabitants of the earth. A connexion was observed between the aspect of the sky, and the changes of the seasons, the rising and setting of certain constellations, and the return of spring or summer. The same tablet was spread out for observation and study before thousands of curious and watchful eyes on successive nights. It was soon ascertained that some of the stars always maintain the same relative position, whilst others wander through the whole circle of the heavens, and thus the first foundations of Astronomy were laid. The earth on the other hand, seemed to present little more than a shapeless chaos as rocks and mountains, without beauty, or order, or value, except to affording a dwelling place for man and other animals, and nourishment for the vegetables used by them for food, and was therefore neglected.

It is true that men had hardly begun to reason, before they began to speculate about the manner in which the world was formed; but they were not careful to establish their theories on a basis of fact and observation. Years rolled on; in other departments of knowledge vast accumulations were made, but Cosmogony—the science of creating worlds, or showing how they might be generated or made, remained stationary, or nearly so, for many years. Bacon appeared teaching the correct method of philosophising, and Newton revealing the secret mechanism of the heavens; but of the composition and structure of the globe, mankind remained as ignorant as before. Wild, intricate, and tiresome romances, called Theories of the Earth, were published ; it was not till the middle of the last century that the rules of the inductive philosophy began to be applied with any considerable degree of exactness to the speculations of Geologists, and it is only within a very few years, that the method of arriving at accurate conclusions in this science has been well understood.

Valuable observations are scattered through writings of an earlier date, but they were neglected. It was between the years 1775 and 1790 that Werner gave, at Freyburg, in Saxony, the new impulse to the study of Geology, which has resulted in all the recent improvements. In 1788, Dr. Hutton, of Edinburg, brought forward a rival theory, which immediately found zealous advocates and supporters, and thus furnished the kind of stimulus that was wanted to give interest to these investigations.—Since the latter date, there has been no want of industrious and ardent observers, and if in so vast a subject much remains doubtful and unsettled, it is nevertheless true, that the conclusions at which we have already arrived, are in the highest degree interesting and important.

As affording a source of rational amusement and subjects for observation and study in after life, if on no higher ground, Geology and the different branches of Natural History, are entitled to a place in a system of liberal education. They change the whole face of nature. No spot is more welcome to the eye of a botanist than a swamp or sand-hill, for there, are those plants of uncommon form and singular beauty which impartial Nature scatters with lavish hand over such localities, whilst she denies them to more genial soils. The more rugged and difficult a road is, the more interesting does it often become to the Geologist, for the strata are laid bare, and he can see the composition, structure, and arrangement of the rocks. But we shall presently see that the science of Geology at least, claims our attention on far higher grounds than these.

OF THE EARTH AS A MASS.

5. Our knowledge of the great mass of the globe is very limited, by reason of our inability to penetrate into its interior. The only particulars in relation to it that have been made the subject of inquiry and investigation, are, its *form*, *density*, *temperature* and *composition*. In regard to the two first, we may claim to have made some approaches to accuracy and certainty, but respecting the others, only to have formed conjectures of whose truth and correctness there is greater or less probability.

6. *Form of the Earth.*—It is commonly spoken of as a sphere, and by those who would be more precise and exact, as a spheroid, having its equatorial about 26 miles greater than its polar diameter.

But it is not a regular and symmetrical figure of any kind. The elevation of the continents, and especially of the table lands that traverse them, produces one kind of inequality, and another is created by the irregular distribution of the denser masses of which it is composed. A large body of rocks of high specific gravity rising nearly to the surface in any part of the ocean, will cause a bulging out of the water around that spot, and the same cause probably operates in modifying the figure of the exterior surface, even in the interior of extensive continents. Leaving out of the account the inequalities produced by the elevation of the land above the ocean, it is not certain that the excess of the equatorial over the polar diameter just stated, is accurate, though it is supposed not to differ widely from the truth, or that the curvature is regular along any given meridian. Observations with the pendulum and the actual measurement of arcs in different latitudes indicate, not only a small variation in the law of ellipticity at unequal distances from the equator, but also an inequality of size, and dissimilarity of form in the two hemispheres on the opposite sides of it.

7. *Density of the Earth.*—The mean density of the earth is about five and a half, that of water being one. But the mean density of the rocks at its surface, is about two and a half. A mass of granite, slate, or limestone, weighs, about two and a half times as much as an equal bulk of water. As the mean density of the earth is therefore, about double that of the common rocks, it follows that it cannot be composed of those rocks *in the state* in which they exist at the surface, but if the material of which it is made be nearly the same in every part, that which is near the centre must be condensed by the pressure of the superincumbent mass into somewhat less than half the bulk it would occupy if it were at the surface.

The density of the earth was first investigated by Cavendish, by means of a large torsion balance, and afterwards deduced by Maskelyne from the effect of a mountain in Scotland, in withdrawing the plumb line from the perpendicular. Cavendish states it at five and a half. Playfair, repeating Maskelyne's calculations, and applying some corrections that were neglected in the first instance, found it to be 4.71. Laplace prefers the determination of Cavendish.

When it was ascertained that the globe taken as a mass, so much exceeds in density the rocks upon its surface, equalling in specific gravity many of the metallic ores, men ventured to draw the inference that it is a metallic body, enveloped in a covering of soil and rock. They then busied themselves with conjecturing what might be the nature of this supposed metallic nucleus, observing that if it were a metal of mean density, it must constitute between a quarter and a third of the whole mass, and if iron, the half. Bakewell suggested that iron nearly in the metallic state may be one of its constituents, and that to this the earth owes its magnetic polarity.

But in a memoir read to the Paris Academy of Sciences, on the 4th of August, 1818, Laplace communicated some new views upon the subject. From the results of observations on the vibrations of the pendulum, he showed, that not only is the matter of the interior of the earth more dense than what is at the surface, but the density goes on regularly and uniformly increasing from the surface to the centre, and the densities are equal at equal distances from the centre in all directions.

These truths having been ascertained and settled, it appears less probable than before, that the high specific gravity of the earth is owing simply to its composition and to the existence of metallic matter in its interior. Upon this supposition the facts would require, not merely that the interior mass should be metallic, but that the metals of which it is constituted should be disposed in concentric shells, the lighter resting upon the heavier, and that these shells should individually be of such thickness, as to produce a *regular and uniform increase of density* as the centre is approached.

The density of the gases is in proportion to the force by which they are compressed. Solids and liquids do not obey the same law, but there can be little doubt that they are all compressible in a greater or less degree. Laplace finds that if we suppose the chemical constitution of the earth to be substantially the same in all its parts, and that the specific gravity of the materials of which it is composed, is moderately increased when they are subjected to pressure, we shall be able to explain, without difficulty, all the phenomena which depend upon the density of the earth.

8. *Temperature of the Earth.*—It is found by observations made in the mines of England, France, Germany and Mexico, and in Artesian wells, that the earth is hotter at considerable depths than at the surface. The temperature increases at a rate which is different for different points, but is supposed to average a degree of Fahrenheit's thermometer, for about forty-five feet of descent. If the heat continues to increase uniformly at this rate, it is evident that the temperature of boiling water (212°) will be found at a level not very remote from the surface, as also that at the depth of a few miles, the rocks themselves are in a state of fusion. The hot springs that gush from the sides of the mountains in most countries, and of which there are several within the limits of the United States, are a proof that an internal source of heat is not confined to the central and western parts of Europe and to Mexico. This subject will receive a fuller discussion on a subsequent page. It may be enough to mention here, that it is the common belief of the ablest geologists, that the interior of the earth is a mass of liquid fire. The mean temperature of the surface of the globe, is estimated by Sir John Leslie, at 67 degrees.

9. *Composition of the Earth.*—It is evident that the fifty-four simple bodies must all belong to the mineral kingdom, and consti-

tute a part of the mass of the earth. But if the interior agree in its composition with the exterior crust, no more than twelve are there in any considerable quantity, the others being of rare occurrence, and entering sparingly into the composition of rocks of moderate magnitude, in the localities where they are found.

The twelve more abundant constituents of the earth's crust are Oxygen, Silicon, Aluminum, Calcium, Magnesium—Hydrogen, Carbon, Sulphur, Chlorine, Potassium, Sodium and Iron, of which the first five are more common, and enter more largely than the others into the composition of the rocks. These are arranged in what is supposed to be the order of their abundance. It is difficult to determine in regard to the remaining seven, what are their relative quantities. These elements form by their union about eleven binary compounds, (oxides and acids with a single exception) which are the proximate elements of the simple minerals; as these minerals are of the rocks that form the crust of the globe. The minerals that constitute 99 one hundredths of the rocks, and that have produced by their decomposition the soil of all countries, are not more than twelve in number, viz:

1. Indurated Clay,	5. Hornblende,	9. Serpentine,
2. Quartz,	6. Talç,	10. Carbonate of Lime,
3. Feldspar,	7. Steatite,	11. Sulphate of Lime,
4. Mica,	8. Chlorite,	12. Iron and its oxides.

These minerals will be further noticed in the order in which they have been mentioned, and a few of their distinctive characters briefly stated.

1. *Indurated Clay.*—Of this substance the common writing and roofing slates, and many of the slate rocks that underlie the central counties of North Carolina, may be cited as examples. In these it exhibits a schistose structure, so as to be readily divisible into thin laminæ, and forms a simple rock by itself; but it is often massive and associated with other minerals.

2. *Quartz*, is a mineral with which every person is familiar under the name of white flint. It often occurs in considerable masses, and under the form of small grains enters into the composition of many of the rocks, forming sand when they are disintegrated. The soil of the low country of North Carolina, is mostly a mixture of quartzose sand and clay. Fused with an alkali and lime, or oxide of lead, it forms glass.

3. *Feldspar*, is easily recognised when we are once acquainted with it, but is not as readily distinguished as some of the others, by a person ignorant of mineralogy, who has only a description to guide him. It has not the glassy lustre of quartz, is less hard, has a laminated structure, is commonly either white or flesh colored. It exists under the form of coarse angular grains, in immense quantities, in the northern and western or granitic counties of North Carolina, of which, along with quartz, it constitutes almost the whole soil.

4. *Mica,* or as it is commonly called, Isinglass, is distinguished by being easily separable into thin, glittering, elastic plates or laminæ.

5. *Hornblende.*—It is to the presence of this mineral in a state of minute division, that the black rocks, called by the planters and farmers, *iron rocks,* owe their color. It also occurs under the form of small irregular crystals, disseminated through other rocks, and when they are decomposed, it appears as a black sand, such as may often be seen in the roads after a rain. On the banks of Salmon Creek, in Bertie county, is found a black sand, consisting of particles of hornblende, with hardly any admixture of a different substance. This is the sand used to absorb the ink, and prevent blotting when haste is required in the transaction of business. In Ashe it forms whole rocks. This mineral abounds in the black oxide of iron.

6. 7. 8. *Talç, Steatite and Chlorite,* from their intimate resemblance, may be regarded as varieties of the same mineral.—They all contain a considerable quantity of magnesia, to the presence of which they appear to owe their distinguishing characters. They are all so soft as to be easily impressed by the nail, and their powder has an unctuous feel. Talç is in thin transparent scales like mica, but is not elastic, and has a pearly lustre. Chlorite is so called from the Greek χλωρος, because the scales of which it is composed, are always of a green color. Steatite is common soapstone.

9. *Serpentine,* is in most cases easily distinguished by its structure, which is massive, its color, which is generally some shade of green or yellow, and its hardness, which is such as to admit of its being cut with a knife. It is found in the northern part of Wake, and in the counties beyond the Blue-Ridge in several places.

10. *Carbonate of Lime.*—Common Limestone needs no particular description. It is distinguished by the effervescence produced when a strong acid is poured upon it.

11. *Sulphate of Lime,* or Gypsum, is a recent rock, and has never yet been discovered in North Carolina.

12. *Iron* is the coloring matter of most rocks and soils.

13. *Water.*—About three-fourths of the surface of the globe are covered with water. The mean depth of the sea has been estimated at two or three miles, but nothing is known upon the subject.

These minerals compose the outer crust of the globe, and have been described under the head of "*Composition of the Earth,*" because there is no evidence that its interior do not resemble (except so far as their condition is affected by their temperature) its exterior parts. But it is the exterior crust of the globe that is the principal object of the science of Geology, and this affords an ample and interesting field for investigation and inquiry.

PRIMARY CLASSIFICATION OF THE ROCKS.

10. All the varieties of rock may be separated into two great classes. The members of one class agree in having a crystalline structure, more or less perfect, indicating that they have once been in a liquid state, and that their particles have been united by a crystallization that is confused, and partial, by reason of the interference of one crystalline form with another. The members of the other class are sometimes made up almost exclusively of the exuviæ of shell-fish ; but more commonly they are composed of rounded pebbles, sand, and clay, that have proceeded from the destruction of the older rocks, by different agents, and especially by water, with only a few organic remains, occurring at distant intervals, imbedded. These materials have been collected and consolidated into masses, having generally, though not always, a texture and aspect which betray their mechanical origin.

There is nothing in the appearances presented by these two kinds of rock, to indicate that they do not alike descend to great depths, and even penetrate quite to the centre of the earth. But the operations of mining ; the scooping out of vallies in the solid body of the continents, by causes that are now in operation, or that have been active in former times ; and observations on the position of the place of separation between them, have brought mankind acquainted with the structure of the crust of the globe, and of the mineral masses that compose it. The members of the second of these classes are found to form only a superficial covering upon the top of the others ; the depth to which they descend being, (at least when compared with the whole radius of the earth), but small.

From their position, resting upon and covering the others, it has been inferred that they are of more recent origin ; that the crystalline rocks were first formed ; that their upper portions have been broken in pieces by the waves and other disintegrating agents, rolled upon each other, and reduced either to small fragments or to powder, and afterwards collected into beds and consolidated, forming the class of which we are now speaking. The crystalline are therefore called primitive, and the fragmented, or those having a mechanical origin, secondary rocks. Amongst the latter, Geologists have found it convenient to introduce certain subdivisions, as the Transition, Proper Secondary, Tertiary and Overlying or Volcanic, which will be noticed more particularly hereafter.

It is perhaps true, that neither the composition and structure, nor the situation of the secondary rocks, nor both taken in connexion, would be *perfectly* decisive of their mechanical origin, and of their having been formed subsequently to the others, if they contained no organic remains. These remains are not found in all the members of the class, but they pervade them so generally, and occur in so great a number, as to be decisive in regard to the origin of the whole. If a rock made up chiefly of rounded pebbles, be found to contain imbedded shells, and another rock agree with it most accurately in composition and structure, except that the shells are wanting, there is ground for the belief that similar causes have operated in the production of both. The distinction between the primitive and secondary rocks is said to have been first clearly marked and stated, by Lehmann, a German philosopher, about the year 1756.

OF MINERAL BEDS, OR STRATA.

11. If a rapid stream empty its waters into a lake, it will carry down and deposit upon the bottom of the lake, gravel, sand, and clay, so that in the lapse of ages the hollow will be filled up and the lake disappear. If we then dig into this mass of alluvial deposits, we shall find it made up of *layers* of different texture and composition. Sand, gravel, and clay will succeed each other, with a great variety in both the order and the thickness of the layers.

The appearances which would be presented by the bed of a lake, or an arm of the sea that has been filled up, are exhibited on a much larger scale, by the fragmented or secondary rocks; but the different layers have a thickness that entitles them to the name of beds. Instead of the words, bed, and beds, Geologists employ the Latin, *stratum* and *strata*, having exactly the same signification, and state respecting certain rocks that they are *stratified;* meaning thereby, that they are in beds placed one above another; and this is true, as well of the primitive as of those that are secondary. The whole series of rocks is therefore divided with reference to their structure into two other great classes; the stratified and unstratified.

When a considerable portion of the crust of the earth, composed of a number of strata, is taken into view at one time, it frequently happens, that it is seen to be made up of a few large masses, bearing little resemblance to each other, but the parts of which, though with slight shades of difference, are much alike, and of which it is therefore inferred that they were produced by the continued operation of the same causes. Such a body of resembling rocks is called a *formation;* but much latitude obtains in the books in regard to the application of this term. The body of sandstone, lying east and south of the University, exhibits many varieties of composition and texture in its remote parts, but constitutes only a single formation.*

* The French language, richer in the terms of art and science than our own, employs the words, *terrain*, *formation*, and *sous-formation;* the first being the name of a genus, of which the others, are species and sub-species. A *terrain* may include several *formations*. But complaint is made as of the English word formation, that there is a want of precision in their application and meaning.

The rocky strata of the globe are seldom parallel, either to the surface or to the horizon. It is but a small number of them that it would be in our power to examine if this were the case. The Himmaleh mountains on the north of Indostan, attain an elevation of about 29,000 feet. The mine at Uttenburg, in Bohemia, (the deepest in the world) descends 3000 feet below the surface. It is probable that it does not reach the level of the sea ; but even supposing it to penetrate 3000 feet beneath that level, it is evident that but a small number of beds can lie between these limits, above and below. The number that would be exposed to view in such a country as ours, is still more inconsiderable. Their thickness would be represented on an eighteen inch globe, by less than that of a single sheet of letter paper—the Himmaleh mountains by less than four sheets.

The strata of the globe are therefore inclined to the horizon, and sometimes at very large angles. Their position furnishes conclusive evidence of the violent convulsions by which the earth has been agitated and torn. Their edges being turned up to the surface, series of strata, hundreds and thousands of feet in thickness are subjected to our observations within the limits of a country that is either level or moderately uneven, and of no great extent, and the evidences of the stratification of the rocks are of much more frequent occurrence than if the position of the beds were universally horizontal.

It is sometimes important that the position of the strata with respect to both the plane of the meridian and the plane of the horizon, should be accurately known. It is ascertained by observations, for determining their bearing and dip, of which the former is measured with the compass, and the latter with an instrument called the Clinometer.

When Geologists first began to notice the position of the rocks, they contented themselves with stating the quarter of the heavens towards which the strata descended or declined, and in a very general way, the amount of declination or descent. When greater precision and accuracy were introduced, it was found most convenient to measure and specify the *bearing* and *inclination* of the strata, and employ the word *dip*, to point out only the side of the line of bearing on which they lie. If a book be placed in an inclined position, with the back resting upon a table, the leaves will represent inclined strata, a line passing lengthwise along the edges of the leaves, will be the line of bearing, and another at right angles to this, along the surface of the leaves, will be the line of dip. The plane angle, contained between the plane of the leaves and the plane of the horizon, is called the angle of inclination.

The situation of an incumbent rock, sometimes corresponds more or less accurately, to that of the rock or stratum, on which it rests, the dip of the two being in the same direction, and the angle of inclination also the same. This is what is called a *con-*

formable position. When the angle of inclination is different, the uppermost is said to occupy an *unconformable* position. The *unconformable and overlying* position, is where a rock lies over the edges of the other stratum. It is the position of lava, and of basalt, from whence, as well as from other circumstances, the latter is inferred to be of igneous origin.

COMPOSITION AND STRUCTURE OF THE ROCKS.

12. The word rock, is used by Geologists, in a sense somewhat different from its common acceptation, for the large mineral masses that form the crust of the earth, whether aggregated into solid bodies, or not. The names and characters of the simple minerals, which constitute the rocks, have been given. Whole mountains are sometimes formed, essentially of a single mineral, as quartz or limestone. In other cases, two or more enter into the composition of the same rock, as in granite; and are either in a state of intimate mixture, or separate and distinct. The masses thus formed exhibit several varieties of structure, as the granular, slaty, laminated or tabular, cellular, which require no definition; porphyritic, when crystals or grains are imbedded in a homogeneous base, and amygdaloidal, where cavities in a rock originally cellular, are filled with matter of a different kind.

WERNER.

13. The southern part of the kingdom of Saxony where it borders on Bohemia, is rich in metallic ores; especially in the ores of silver, copper, lead, tin, arsenic, cobalt and iron. A school of Mines is maintained by the Saxon king at Freyburg, within the limits of the metalliferous district, for the education of such persons as are to be employed in the extraction of the ores from the earth, or in smelting them when brought to the surface of the ground.

In this institution, Abraham Gottlob Werner, then twenty-five years of age, received the appointment of Professor of Mineralogy, in 1775.* He became the benefactor of this science, by giving precision and accurracy to its language, as well as by his skill in the discrimination of mineral species, and if his system of description and classification are not perfect, we must not, in estimating his merits, forget what Mineralogy was when it passed into his hands. But Werner is most extensively known and celebrated as a Geologist. He created an interest in his own favorite pursuits and studies, by pointing out the application of a knowledge of the earth's structure, to the practical purposes of mining; yet it is not easy to account for the influence excited by him for so long a period over the opinions of men. His opportunities for observation were excellent, and discovering that the

* He died at Dresden in 1817.

mineral masses of which the crust of the earth is composed, are not distributed at random, but placed one above another in a certain order of succession, and that mineral veins and beds occur in some kinds of rock and are wanting in others; he was led to speculate respecting the causes by which they had been produced, and to the formation of a Theory of the Earth. He published but little. His doctrines were communicated in his lectures, delivered at Freyburg, to students collected from all parts of Europe. These lectures were written out by the most approved members of his classes, and revised by himself, so that we have accurate information respecting his opinions.

It is regarded as a decisive proof of the ability and merit of Socrates, that he was able to inspire two such men as Plato and Xenophon, with an attachment to his person, and a respect for his character and opinions, which led them to devote a considerable portion of their lives to the task of recording the most striking incidents in his history, and illustrating his doctrines. A corresponding evidence of transcendent genius, is furnished by the influence exerted by Werner over the minds of his pupils. What was most remarkable in himself, was an energetic determination of all his powers, to the advancement of the kindred sciences of Mineralogy and Geology, and he inspired them with more than his own enthusiasm. They ransacked the continent of Europe for illustrations of his theories and proofs of their truth and correctness, and his doctrines were propagated by writings and lectures throughout the civilized world. Since his death, more extensive and accurate observations have made us better acquainted with the crust of the earth, and his principles are one by one abandoned. He fell into the error of the early philosophers, of generalizing from too narrow an induction of particulars, and fondly believed the little mountains of Saxony, to present a type of the world. Nor is this all. It is now ascertained that he either failed to notice, or misinterpreted, many important appearances, even in the immediate neighborhood of Freyburg.—Yet in every course of Geological lectures, the name of Werner must be mentioned with respect, and his theories unfolded. The subject is brought forward in this place, because some of the terms introduced by him into the science appear in the following account of the rock formations, and his general scheme of arrangement is adopted.

WERNER'S THEORY.

14.—1. *Primitive Rocks.*—Werner taught that in the beginning, what are now the solid materials of the globe, were dissolved in the waters of the ocean, so that the whole earth was a chaotic, fluid, or semifluid mass. In this, an attractive energy of particle for particle was presently exerted; crystallization commenced, and immense bodies of rock were immediately consolidated, forming the central nucleus of the globe. But as in crystallization the force of cohesive attraction prevails over that of gravitation, the central nucleus did not form itself into a perfect sphere, but shot up into ridges, constituting the mountain ranges of granite and other crystalline rocks that now traverse the surface of the globe.

The water being thus freed in part from the substances which it held dissolved, there was a different play of affinities, and a different species of rock, (gneiss), was formed and deposited; upon this a third, (mica slate), the successive strata extending themselves in general, like the coats of an union, quite round the globe. It was only in a few situations, effected by peculiar circumstances, that crystalline deposits of a limited extent, were formed. Thus all the varieties of primitive rock came into being.

2. *Transition Rocks.*—The waters, still charged to some extent with mineral matter, retired in part into vast caverns in the central parts of the earth, and the mountains emerged; in part they became the abode of the lower orders and more imperfect kinds of shell-fish; they were agitated by furious winds, and the fragments of rocks contained within their bosom, being rolled one upon another were rounded, and finally collected into immense beds, enveloping the exuviæ of shell-fish, and consolidated. The primeval ocean also continued to deposit, though less abundantly than before, the substances it still held dissolved, sometimes amongst the mechanical aggregates just mentioned, and sometimes in separate and distinct layers. The transition rocks are therefore partly crystalline and partly mechanical deposits. They received this name because during their formation, the earth was passing from an uninhabitable to a habitable state.

3. *Secondary Rocks.*—The sea continuing to retire, its shores became the habitation of the various kinds of plants and animals, and eventually the secondary, made up chiefly of the ruins of the older strata, were formed in a similar manner. With some crystalline masses and beds, they are generally of a more earthly texture than the transition, and embrace vegetable matter, retaining sometimes its original form, and the exuviæ of animals inhabiting both land and water. They were called *flœtz*, or *horizontal* rocks by Werner, because he supposed them always to occupy that position.

4. *Basalt.*—Last, a great convulsion, a deluge supervened. The waters of the ocean rose out of their bed, stood over the tops of the loftiest mountains, and covered the whole surface of the earth with a coating of *basalt*, which was however broken up, and in a great measure swept away by them as they retired, leaving only a few patches scattered over the rock formations of some countries. This particular in Werner's theory, appears to have been added with the double purpose of bringing it into perfect harmony with the sacred Scriptures, and of accounting for certain masses of basalt that repose on the summits of the mountains between Freyburg and Bohemia.

5. *Alluvial Rocks and Soil.*—After the waters of the deluge had retired, the rocky strata that had been left bare, were reduced in some cases to a coarse gravel or to powder, and the finer particles washed down and deposited, intermixed with vegetable and animal matter, in the vallies, either upon land or in the bed of the sea. Rocks of volcanic origin, were regarded by Werner, as occupying too small a space on the surface of the earth, to merit particular notice.

Such is Werner's theory. As he was an excellent mineralogist, and an earnest and intelligent observer, it may be expected that whatever be the fate of his theory, the distinctions established by him amongst the rocks, will commend themselves to the judgment of the Geologists of succeeding times. One of his errors, was that of allowing too little space and importance to the formations of volcanic origin, and refusing to include basalt amongst them. In the place of his class of alluvial, that of tertiary formations has been substituted, leaving the whole number still the same. 1. Primitive, 2. Transition, 3. Secondary, 4. Tertiary, 5. Overlying or Volcanic.

OF GRANITE.

15. Our attention will be first directed to the primitive rocks, and first of all to that, which according to Werner, was first separated by crystallization from the original, semifluid, chaotic mass; which is the central nucleus that underlies all the other strata, which also pierces through them, and exhibits its rugged and barren head, on the summits of some of the loftiest mountains. This is granite. The other primitive rocks, gneiss, mica slate, quartz rock, clay slate, limestone, and serpentine, will follow. A few that resemble mica slate in their structure, but differ from it in their composition, will be most conveniently treated of under that title. These are the chlorite, talcose, hornblende, and actinolite schists.

Proper granite is a granular aggregate of the simple minerals, quartz, feldspar, and mica; the feldspar being generally the most abundant of the three, crystalline in its structure and unstratified. It has evidently been produced by an irregular and imperfect crystallization. It presents itself at the surface of the earth, in large masses, the sharp angles of which having been obliterated by the action of the elements, they often make some distant approaches to a spherical form. The name it bears, appears to have been applied without much precision to certain stones employed in architecture and statuary, with reference to their granular structure, before the time of Werner, and to have had its meaning first fixed and limited by him to a particular rock. Besides the proper granite just described, there is a considerable number of rocks, like it of a crystalline and granular structure and unstratified, but differing from it in their mineral constitution; some containing hornblende, chlorite, or talc, instead of mica, some containing only two ingredients, and others more than three, all of which it has been found convenient to include under the same general name. All the different forms of granite that are to be described, graduate into each other, and they are often to be found within moderate distances in the same rock.

1. *Quartz, Feldspar and Mica.*—This is proper granite, and the most common of all the varieties. It is sometimes rendered porphyritic by large irregular crystals of feldspar, imbedded in a fine grained mass, constituted of these three minerals. A beautiful granite of this kind, is seen on both sides of the Pedee, in Anson and Richmond counties, between Old Mount Pleasant and Sneedsborough. It occurs also in Lincoln county, between Morganton and the Island ford of the Catawba.

2. *Quartz, Feldspar and Hornblende.*—This is what is sometimes called Syenitic granite. It is found on the road to Pittsborough, three or four miles from the University.

3. *Quartz, Feldspar and Chlorite.*—The name of Protogine was applied to this and the next following variety, because on account of their being very abundant in the central masses and pinnacles of the Alps, they were supposed to be amongst the very oldest of the rocks; but as the granites of the Alps are now placed amongst the more recent formations of that substance, the name is no longer applicable. Rocks resembling most intimately the specimens of protogine, brought by Dr. Caldwell from the vale of Chamouny, may be seen half a mile west of the University.

4. *Quartz, Feldspar and Talç.*—Imperfect specimens have been noticed half a mile beyond Haw River, on the road leading through Randolph to Salisbury. It is common in the county of Cornwall, (Eng.), where more than twelve thousand tons are raised annually, under the name of China stone, or China clay, for the supply of the English potteries. In this particular locality it contains no iron, and its feldspar is therefore suitable for the production of a porcelain that will come perfectly white from the furnace.

5. *Feldspar and Quartz.*—There is sometimes an uniform mixture of these ingredients, and sometimes the quartz and feldspar are aggregated in lengthened parallel prisms, so that when a piece is broken across the quartz prisms, the surface that is produced presents the appearance of the characters used in writing by some of the ancient nations. Hence it is called Graphic Granite. Broignart says, that all the fine kaolins used in the manufacture of French (?) porcelain, are derived from graphic granite.

6. *Feldspar and Hornblende.*—This is a very important variety of granite, offering an almost endless diversity of appearance, dependent upon the proportions, color, crystallization, and mode of admixture of the ingredients. Some of its forms have received the name of Syenite, from the town of Syene in

Upper Egypt. A very hard and beautiful granite of a reddish color, with black mica and a very small proportion of hornblende, was quarried at this place by the ancient Egyptians. Cleopatra's needles and Pompey's pillar at Alexandria are formed of it. Two obelisks now at Rome, have withstood the attacks of the weather, and retained their original beauty after a lapse of three thousand years. Werner, mistaking the composition of a specimen of this Egyptian granite, and supposing it to be the *binary* compound of which we are speaking, gave the name of Syenite to those compounds of feldspar and hornblende, in which the latter ingredient is in distinct and separate crystals. By some Geologists the name is restricted to rocks of this constitution, belonging to the overlying or trap family. Very handsome primitive Syenite, is found in a number of different places in the neighborhood of the University. In this the feldspar predominates, and is of a whitish color. But more commonly it is the hornblende that is the prevailing ingredient, and communicating to the rocks its own color, and the property, in consequence of the quantity of iron it brings into their composition of decomposing into a red soil, it gives rise to the denominations of black rock and iron rock, by which they are commonly known. When the hornblende predominates greatly, and is crystalline in its structure, the rock is the primitive trap of Werner. When there is a more intimate mixture of the ingredients, it cannot be distinguished from the greenstone of the old red sandstone formation, and finally, it is sometimes of so compact and uniform a structure that it has all the mineralogical characters of basalt, of which the natural walls in Rowan are an example.

7. *Granite composed of four Ingredients.*—Of the granites containing four ingredients, and other rare and uncommon varieties, it will be enough to remark, that almost any four of the constituents of this rock, quartz, feldspar, mica, hornblende, chlorite, talç, and some other minerals, may sometimes be found associated with each other, and that the glassy and compact are sometimes, though rarely, substituted for common feldspar.

According to McCulloch, granite is an unstratified rock, and, in general, it exhibits no traces of stratification. Yet it is said by Jamieson to be sometimes stratified. This appears to be the case with some of the granites of Wake county, between Raleigh and the Neuse river, if not with others in the state of North Carolina. Granite is frequently divided by seams or fissures into beds, prisms, and cuboidal masses. When into prisms, it is called columnar granite, of which there is an example on Haw River, between Chapel Hill and Pittsborough. Balls of a very hard and indestructible granite are sometimes imbedded in a softer variety, which undergoing decomposition, permits the balls to fall out. This kind of structure may be seen at the mill, a mile N. East from Rockingham, in Richmond county. That of Corsica, where this variety first attracted attention, is particularly remarkable for being disposed in concentric layers. Granite is often traversed by veins.

A great diversity of aspect is exhibited by different granites, even where the ingredients are the same, depending upon the color of the ingredients, the greater or less perfection of their crystallization, and the size of the grains. Some undergo decomposition rapidly, and to a great depth, as in Caswell. Good mill seats are rare where the rocks have this character. Other granites remain unchanged, though exposed to the action of the elements for a very long time. The flat rocks of Franklin, Rowan, and Stokes, furnish a striking illustration. Whilst the crust of the globe about them has been converted into soil, they have remained apparently unchanged from the time of their formation to the present day. They have a vegetation of their own. Plants are found growing upon them that are not met with elsewhere for many miles, and some that are altogether peculiar to them.

Granite is a common and widely distributed rock. It occurs in almost every great range of mountains, of which it generally forms the central and highest parts, having the more recent formations resting upon it. It occupies a lower level in America than on the eastern continent. With the exception of Montgomery, where, if it exists at all, it is recent and imperfectly characterized, there is no one of the upper counties of North Carolina, that does not contain more or less of it. Werner supposed all the granite rocks to have been formed contemporaneously, and to be therefore of the same age. It is quite certain that this is not true. The granite of the eastern and western counties, Warren, Franklin, Wake, Lincoln, Rutherford, Burke, Wilkes and Surrey, appears to be older than that occupying a part of the intervening space in Granville, Orange, Caswell, Guilford, Davidson, Rowan, Cabarrus and Mecklenburg.

The minerals that are found imbedded in granite are numerous, but in general not valuable. It is not rich in the metallic ores. The tin mines of Cornwall and of Saxony, are in granite, and it also embraces beds of iron ore. This rock is indeed so widely distributed over the surface of the globe, that it was to be expected that on searching the whole world over, mines of most of the metallic ores would be found in it; but where they exist they are generally poor, and will not repay the expense and labor of working them.

OF GNEISS.

16. The second rock in the Wernerian arrangement is gneiss, which is said to rest upon and cover the granite, and to be itself covered by the other strata. The minerals which enter into its composition are the same with those that form granite, but the proportions are different and they are differently arranged. Proper gneiss is constituted of quartz, feldspar, and mica. The mica is frequently more abundant than in granite, and is so dis-

posed that there is at least an approach to parallelism amongst its laminæ. In general also, instead of being dispersed through the whole body of the rock, it is separated from the other ingredients into plates or seams, by which the granular compound of quartz and feldspar is divided into tables of greater or less thickness, so that if a small piece of gneiss be examined, it will appear to be granular and massive, if a large mass be subjected to observation, it will as evidently be stratified and slaty.

For mica, there is often substituted in the composition of gneiss, hornblende, and sometimes, though rarely, talç, chlorite, or argillite. The variety containing hornblende is found abundantly amongst the mountains in the western part of North Carolina. Besides the varieties produced by the substitution of these substances for the mica, there are many others created by the disappearance, or by some modification of the arrangement of the quartz and feldspar, so that the rock passes into granite on the one hand, and into the formations to be immediately noticed, mica slate and quartz rock, on the other. Like granite, it is rendered porphyritic by the superaddition of large crystals of feldspar, and takes the name of porphyritic gneiss. Fine examples of this may be seen at Graham's furnace and in other parts of Lincoln county, and in the ascent of the Blue-Ridge, by the way of the Hickory-nut gap, in Rutherford county. The court-house in Burke, is built of this variety.

That variety of gneiss which abounds in mica, has less firmness and solidity than granite, it is less beautiful, but being divided by the seams of mica into tables, it is quarried with greater ease, and if it be of a kind that will stand the weather, in which particular, gneiss is generally superior to granite, it is in request as a building stone, and for other economical purposes. A quarry of the hornblende variety has been explored for many years, at Durham, in the state of Connecticut. It is raised in tables, varying from an inch to two or three inches in thickness, and shipped to the large cities along the coast, where, on account of the evenness of its surface, it is much esteemed as a flagging stone. Gneiss is one of the most widely distributed of the rocks. In North Carolina it is found along the Cape Fear in the upper part of Cumberland, and in the western counties.

The crystalline mineral forms, which are sought after with so much eagerness by collectors, and esteemed the most valuable ornaments of our mineralogical cabinets, are not as numerous and abundant in gneiss as in granite; but it often embraces extensive formations of other rocks, as limestone, porphyry, compact-feldspar, and quartz, and it is rich in the metallic ores. Most of the metals occur in it, sometimes in beds, but more frequently in veins. Many of the mines of Germany and Sweden are in gneiss. The most valuable beds of iron ore, in the western part of North Carolina, are in a region where gneiss abounds, but the ore is frequently in immediate contact with some other rock.

OF MICA SLATE, OR MICACEOUS SCHISTUS.

17. The characters by which granite and gneiss are determined and distinguished from other rocks, are drawn from their structure, rather than their composition. The proportion of the ingredients may vary, one of them may disappear and be replaced by another mineral, and still the application of the same common name, involves no absurdity, and produces no obscurity. The hornblende, chlorite, or talç, which takes the place of the mica, effects but an inconsiderable change in the appearance and characters of these, as distinguished from other rocks, and forms, therefore, only an unimportant variety. But in the combinations that are immediately to follow, these substances, instead of occupying a subordinate place, become the predominant ingredient, and give rise to well marked and important distinctions. There is therefore a necessity for the separation of rocks, apparently of the same age, alike in their structure, and differing *in the same way*, that mere varieties of granite and gneiss differ from each other, into five or six distinct species—mica slate, quartz rock, hornblende schist, chlorite schist, and talcose schist, to which McCulloch adds actinolite schist. All these have a schistose structure, more or less perfect.

Mica Slate, or Micaceous Schist, succeeds to gneiss in the Wernerian arrangement. Its essential ingredients are mica and quartz. By the loss of one of these, the substitution of another mineral, or the acquisition of a third, it passes into quartz rock, the other varieties of schist, and gneiss. Like gneiss, it embraces subordinate beds of serpentine and limestone, and like it, is also rich in the metallic ores. The laminæ of which it is composed, often present numerous undulations and contortions. Of the earthy minerals, that in which it most abounds, is garnet, which is sometimes so abundant as to equal in quantity the including rock. Well characterized mica slate does not occur in North Carolina, except in the upper part of Cumberland, and in the western counties. It may be seen near the dividing line of Rockingham and Stokes on the south side of Dan river, in Surrey, Lincoln, Ashe, and Buncomb, where it sometimes contains octahedral crystals of the oxide of iron, in such quantities as to constitute a valuable ore of that metal.

Quartz Rock, was regarded by geologists as a variety of mica slate, and treated of under that title until it was separated by Dr. McCulloch, and had assigned to it a place amongst the rocks, to which, from the space it occupies in the crust of the globe, it is well entitled. It is a stratified rock, consisting either of pure quartz, compact or granular, or of grains of quartz and feldspar, or quartz and mica. It seldom contains any imbedded minerals, whether metallic or earthy. The granular variety sometimes admits of a considerable motion amongst its particles, without being broken, constituting a flexible sandstone, of which Stokes county furnishes examples. Quartz rock is reduced to powder, and used in the manufacture of glass, and in Lincoln it is preferred to every other substance in the construction of their iron furnaces. It occurs about ten miles from Raleigh, on the road leading to Chapel Hill. In the Pilot, Sawra-town, and King's Mountains, it prevails almost to the exclusion of every other substance. They have also the insulated appearance, and tendency to a conical form, mentioned by Brande, as characteristic of mountains formed of this rock.

Hornblende Schist, is a stratified rock, composed either of pure hornblende, or of hornblende and feldspar. It is the primitive greenstone of some Geologists. The hornblende it contains communicates to it a dark color, by which it is always characterized. It seldom contains any imbedded minerals. It has been met with about the falls of Neuse; an imperfect and ill defined variety occurs in the eastern part of Davidson county; it is also found amongst the western mountains, as around Jefferson in Ashe county, where it is associated with gneiss.

Chlorite Schist, is constituted either of simple chlorite, or of chlorite and quartz, and is easily distinguished by its green color. It appears to underlie the sand of the low country, near its upper border, through the counties of Johnston and Cumberland, as it is found in the banks and beds of the Neuse at Smithfield, of the Cape Fear, above Averysboro', and of Lower-Little-River, at the mills, formerly owned by Col. Benjamin Williams. It occurs also in Wake, Orange, and the western counties.

Talcose Schist, differs from the last in containing talç, instead of chlorite. It is not a common rock, but is found in Ashe, in the Meat-camp settlement, where it contains oxydulous iron, and in the northern part of Wake, not far from the Neuse. There is a rock on the road leading from Raleigh to the University, at the distance of from six to nine miles from the city, which seems to hold an intermediate place between micaceous and talcose schist. It has an unctuous feel, indicating the presence of a quantity of magnesia, and at some points embraces beds and masses of plumbago.

OF THE SIMPLE PRIMITIVE ROCKS—SERPENTINE, LIMESTONE, CLAY SLATE, Etc.

18. These require no description, other than what they have already received. Serpentine occurs almost exclusively amongst the primitive rocks, where it seldom forms very considerable masses. It abounds in imbedded minerals. It is found in the northern part of Wake, and in the counties west of the Blue-Ridge. Steatite and compact-feldspar, enter as members of both the primitive and transition strata, whilst limestone, quartz, and argillite or clay slate, under some of their forms, extend through

the whole series of formations, from the primitive (limestone and quartz from the most ancient primitive) to the most recent alluvial ; nor is it possible, often, to tell, with mere hand specimens before us, to which of the great classes one of these rocks belongs. Thus the argillite at Barbee's mill, might be regarded as primitive, until we find it alternating with rocks that are beyond all doubt transition—and so of the hornstone, until we find it graduating into, and forming part, of a rock that is made up of pebbles and sand.

In all these cases the rule of morals, "*noscitur a socio*"—its character may be determined by observing that of its associates, is to be applied. Wherever we find well characterized granite, gneiss, or mica slate, the mass of the mountains in which those rocks occur is to be regarded as primitive, until facts are produced which prove parts of them to be of more recent origin. Subordinate beds of argillite, hornstone, compact-feldspar, limestone, serpentine, or quartz, amongst those primitive rocks, are to be presumed to be themselves primitive, whilst the same substances associated with transition rocks, are to be regarded as transition. Small bodies of rock, having the distinctive characters of argillite, are found amongst the primitive mountains of the western counties. It abounds in our transition strata. Primitive limestone is rare, but there are beds of it in Stokes, Surrey, and Buncomb, where it is raised and burnt into quicklime. Primitive soapstone is found in Warren, Wake, Iredell, and probably in many other counties. Compact-feldspar occurs amongst the recent primitive rocks on Chapel Hill.

Before proceeding to the transition rocks, it may be remarked respecting the class we have just finished, that the granite generally underlies all the others, as the Wernerian theory requires ; but not always. It frequently rests upon both gneiss and mica slate, or alternates with them. The lowest of all the rocks, the floor or foundation stone, upon which the others rest, is supposed in all cases to be granite. On this is superimposed a stratum of gneiss or mica slate, then a layer of granite, upon which comes a stratum of the other member of the series. *Granite also traverses the other rocks, under the form of veins. The most decisive evidence is furnished, where this occurs, that the imperfect crystallization it exhibits, is not as Werner supposed, from aqueous solution, but is the result of cooling from an igneous fusion. These veins must also be more recent than the including rock.* In the Western mountains, the granite, gneiss, and mica slate, are contemporaneous formations, as is proved by the fact of their alternating with and passing into each other in a thousand different ways. These changes are particularly remarkable on the road from Wilkesboro' to Jefferson, in the ascent of the Blue-Ridge. All granite is not of the same age, or was not formed at one time. The granite of Chapel Hill is more recent than that of Wake or Wilkes.

OF THE TRANSITION ROCKS.

19. The transition are distinguished from the primitive rocks, either by being made up of the rounded fragments and ruins of more ancient formations, or by their resting upon and covering rocks that are so constituted: and from the secondary, by the absence of organic remains, or their containing such only as belong to the lower races, and more imperfect forms of animal life. By some geologists this division is rejected, and its members referred to the primitive class. They divide the whole series of formations into four great classes, the *primary*, *secondary*, *tertiary* (embracing very recent deposits of sand, clay, and shells) and *overlying*, including the products of volcanoes. No very valid reasons are offered for the exclusion of the *transition* class. It is said that there are no fixed and manifest lines of demarcation and boundary, by which to separate the transition from the primitive rocks on the one hand, and from the secondary, on the other. But the same difficulty occurs, however numerous or few the classes we form. From the era of the formation of the most ancient rocks, (whether by the hand of the Deity, or the agency of second causes) to the present time, the forces have been in constant activity, by which the condition of the crust of the globe has been changed, existing strata destroyed, and new ones formed and consolidated out of their ruins. There has been no interval of repose, the closing event of an antecedent order of things, and the precurser of a new; such an epoch in the history of nature, that the strata formed before and after it, fall of themselves into classes, separated by well marked and important distinctions. The object of our classification of the rocks, must therefore be, to separate the long chain of events, reaching from the remotest period of time to the present day, and the effects—the rocky strata they have created and left behind them—into such portions and families as may be conveniently associated with each other. Geologists will differ in their views of expediency in the case, according to the nature of the formations about them, and with which they are familiar. Where the transition rocks occupy but a small space, they will be merged in the primitive class; but where, as in North Carolina, it is the secondary class that disappears in a great measure, if not entirely, we may be excused if we retain the old landmarks of the science, and distribute the rocks into five classes, the primitive, *transition*, secondary, tertiary, and overlying or volcanic.

The rocks of the transition are less distinctly characterized than those of the primitive class. Where, as in the case of limestone, argillite, and soapstone, varieties of the same simple mineral enter as members of the two formations, that belonging to the transition is generally characterized by a more earthy aspect, and less crystalline structure. There are three or four kinds only of transition rocks, agreeing in this one particular, that they are formed principally of the consolidated fragments and ruins of older formations, which will require a particular description. They pass into each other by insensible shades, and though in some cases it is easy, it is in others impossible to determine, by its mineralogical or natural-historical characters, to what divison a given specimen is to be referred. They are all included by McCulloch, under the single denomination of Argillaceous Schistus, of which he regards them as mere varieties.

OF ARGILLACEOUS SCHISTUS OR CLAY SLATE.

20. This substance affords a good illustration of the difficulty just stated, of separating the strata of the globe into well defined and distinct classes. It generally *covers* granite, gneiss, mica slate, and the other rocks that are unquestionably primitive; from which it is inferred that it is itself of more recent origin. But it also alternates, though in beds generally of inconsiderable thickness, with those substances, shewing that it had begun to be deposited, whilst the causes that gave being to those rocks were still in operation. On the other hand, small beds of granite, gneiss, and mica slate, occur amongst strata that are made up of the fragments of older rocks, proving that the formation of rocks by the agency of chemical affinity did not suddenly and entirely cease when the mere mechanical aggregates began to be deposited.

Under the single denomination of argillaceous schistus, McCulloch includes, as has been stated, a number of substances unlike each other, and that have heretofore been treated as distinct species. They are generally mechanical aggregates. They differ in composition and the fineness of their constituent particles or fragments, but are so intimately associated and pass into each other by such insensible gradations, and at such moderate distances, that it is thought they should be regarded only as forms of the same rock. A few of the more common and marked varieties will require a particular notice.

Proper Argillite or Clay Slate, is a common substance in North Carolina, where it generally exhibits a disposition to split by the action of the weather or of mechanical force into thin laminæ, though some varieties merely separate into tables which are without any indications of a schistose structure. It enters largely into the composition of the great transition formation that stretches through the central counties. The part of this formation lying in Anson and Mecklenburg is made up almost exclusively of this rock. On the Pedee it is seen at Parker's ford about the South Carolina line, at the Grassy Islands, the mouth of Rocky river, and from the latter point, at intervals, as high as the mouth of Flat-swamp creek in Davidson. It abounds in Montgomery, Randolph, Moore, Chatham, Orange and Person. It is the lowest rock as we descend the Neuse, occurring about

Micajah Coxe's in Wayne. There is also a small formation of argillite about Nash court-house, and extending from thence in a north-easterly direction towards Fishing creek, probably including Dozier's gold mine, and connected also under the sand with that at Coxe's. The western part of the westernmost county in the state, (Cherokee) contains much argillite, as does the tract stretching thence towards Virginia along the border of Tennessee.

Flinty Slate makes its appearance four or five miles west of the University on the road leading over Mount Willing, where it is porphyritic—at the Great Falls of the Yadkin, and other places in the transition formation. It is much harder than argillite containing a larger proportion of quartz or silica.

Whet Slate or Novaculite, is obtained of a good quality six and a half miles west of the University, and in the northern part of Chatham on the west side of Haw river. In these localities it evidently contains a quantity of magnesia, as is stated by Bakewell to be the fact with regard to this variety of slate.

"*The far-famed illustrious, Grau-Wacce*," *or Gray-Wacke*, is described by Jamieson as "composed of irregular or other portions of quartz, feldspar, Lydian-slate, and clay-slate, cemented together by means of a basis or ground of the nature of clay-slate, which is often highly impregnated with silica, thus giving the mass a considerable degree of hardness. The imbedded portions vary in size, but seldom exceed a few inches in breadth and thickness." Cleaveland says they pass from nodules one foot in diameter, to grains which are scarcely perceptible to the naked eye. "When the imbedded portions become very small, the rock assumes a slaty structure and forms gray-wacke slate. When the grains almost entirely disappear and the rock is principally composed of clay-slate, it is called transition clay slate."

We have many rocks amongst our transition strata, and in our immediate neighborhood, which answer well to Jamieson's definitions; but they are probably more ancient than the rock bearing the name of grau-wacce in Germany, and have a different aspect. They bear little resemblance to the gray-wacke of the Alleghanies. It is perhaps better to refer them to the Conglomerates—a convenient class, admitting almost any rock constituted of the fragments of older formations.

Gray-wacke, especially the slaty variety, is extensively distributed through the crust of the globe. It is found in Germany, constituting a considerable part of the celebrated Hartz mountains, in the Alps, in Scotland, in the United States about Boston, and in that part of the Alleghanies which lies west of the primitive. It abounds in the metallic ores. The gray-wacke of the Hartz yields silver, parts of that within the limits of the United States are rich in the ores of iron.

Of the Conglomerate Rocks, the strata about Barbee's mill, composed of pebbles of quartz, hornstone, siliceous, and clay-slate, and other substances cemented by finer particles or a homogeneous paste of the same material, afford very fine examples. In some of these the pebbles are large, of fine texture, and exhibit a great variety of colour. These if cut and polished, which by reason of their great hardness would be a difficult operation, would be very beautiful. In others the grains are so small that the mass constitutes a kind of fine sandstone. In some the pebbles make up almost the whole mass of the rock, in others they appear only here and there, thinly scattered through the basis in which they are imbedded. Conglomerates may be seen about Hillsborough, Pittsborough, Lawrenceville, in the western part of Randolph, and at some of the principal gold mines within the limits of the transition formation.

A Breccia differs from a conglomerate in but one circumstance. The imbedded fragments, instead of being rounded by attrition, are angular. Both this and the conglomerates are siliceous, argillaceous, or calcareous, according to the mineral character of the fragments and cement of which they are composed. Of a calcareous breccia the beautiful pillars of the capitol at Washington may be cited as an example.

OF THE SANDSTONES.

21. The name of these rocks indicates what they are. In their composition, structure, and colour, there is a considerable variety. They consist chiefly of particles of siliceous sand, held together by a cement which is generally small in quantity, and sometimes apparently, by an attraction of aggregation exerted directly between themselves. The sandstones are evidently of very different ages, but still bear such a resemblance to each other that they must be distinguished by their geological position, and relations to other rocks, rather than their mineral characters.

1. In the northwestern part of Scotland there is a sandstone which alternates with gneiss and quartz rock, and also with gray-wacke, and which must therefore be accounted one of the oldest members of the transition class.

2. A stratum of sandstone, generally of a red colour, intervenes between the transition and secondary rocks in certain parts of England and Scotland, which is referred by some geologists to the former, and by others to the latter class. It is composed of particles of sand, generally with a mixture of mica, and sometimes of feldspar, or carbonate of lime, united by a cement of ferruginous clay, which is seldom abundant. It is called the old-red-sandstone, but geologists seem inclined at present to regard it as a variety of gray-wacke. It underlies all the mines of fossil coal that have been discovered on the island of Great Britain. They are either imbedded in it, or what is more common, separated from it by one or two intervening strata.

3. Another stratum of sandstone of more recent formation than the last, as is proved by the circumstance of its being above the

coal, composed of grains of sand united by a cement of clay or carbonate of lime, passes through the central and western parts of England, where it is known by the name of red-marle or new-red-sandstone. It embraces mines of rock salt and gypsum.

4. Above the new-red-sandstone other sandy strata occur, which are sometimes consolidated into a rock.

5. A very ancient sandstone extends from the Tennessee line through a part of Ashe, Yancey and Burke counties, along the Linville river and mountain to the Catawba. It alternates with clay-slate, and has associated with it beds of limestone. The same kind of rock is seen on the French Broad, about, and below the Warm Springs. Prof. Troost calls this last grau-wacke.

6. A formation of sandstone associated with clay-slate enters North Carolina from Virginia by the bed of Dan river, and traversing Rockingham and part of Stokes, ends near Germanton. It embraces at least one bed of anthracite coal.

7. A long bed of sandstone commencing in the northern part of Massachusetts, stretches with some interruptions, through the intervening states into South Carolina. It approaches within a mile of the University on the east, and occupies a breadth of about sixteen miles on the road leading to Raleigh. It contains beds of bituminous coal in Chatham.

8. About Fayetteville and perhaps elsewhere in the low country, are more recent sandstones, that have sometimes solidity enough to admit of their being employed in building.

9. Other beds and varieties of sandstone are found amongst the Alleghany mountains and in the western states.

What kind of relation do these different sandstones bear to each other? Is any individual amongst the strata of England of the same age with a corresponding German or American rock? Has it been produced by the same causes? It is not easy to furnish an answer to these questions that shall be altogether satisfactory.

Werner distinguished certain varieties amongst the sandstones in the neighborhood of Freyburg. He classed them by their mineral characters and geological relations, and designated them by the names they bore amongst the German miners; for which however others were afterwards substituted. Of these the Rothe-todte-liegende or red-dead-lier, the most ancient of the sandstones that fell under the observation of Werner, has been rendered particularly famous by the controversies to which it has given origin.

Freyburg was for a time the great geological school of Europe, to which young men resorted from the British islands as well as from distant parts of the continent, for the purpose of acquiring a knowledge of the science. They there became acquainted with the different kinds of sandstone distinguished and described by Werner, and when they afterwards entered the field of observation, were anxious to find the same rocks, or rocks to which the same name might be applied amongst the formations of their own country. For his rothe-todte-liegende, an equivalent was supposed to be found in an English stratum underlying the coal formation, and called the old-red-sandstone—for his weiss-liegende in the new-red-sandstone, and for the others in the higher beds.

The Americans, deriving their knowledge of Geology from English rather than continental publications, have pursued a similar course, and endeavoured to refer their sandstones to some of the rocks bearing the same general name on the island of Great Britain. Thus, the sandstone formation mentioned as commencing in Massachusetts, and extending through the intervening states into South Carolina, has been called the old-red-sandstone.

But recently, British Geologists have placed the old-red-sandstone amongst the gray-wackes, and find in the upper and lower members of the *new*-red-sandstone, the equivalents of the weiss-liegende and rothe-todte-liegende of Werner. What is now to be done with the sandstone of North Carolina and the other Atlantic states? Is it to go along with the old-red-sandstone of England amongst the gray-wackes, or to be regarded as the equivalent of the rothe-todte-liegende, or does it correspond to neither? We cannot tell. If doubt and uncertainty hang for years over the relations of the strata of England and Germany, separated by an interval of only four or five hundred miles, it may well be expected that it will not be less in the case of rocks lying on the opposite sides of the wide Atlantic. The sandstone is in contact with the conglomerate rocks of the transition formation in our neighbourhood, but bears no more resemblance to them than granite does to mica slate. It probably is not more ancient than the old, nor more recent than the new-red-sandstone of the English strata, but no satisfactory evidence has been furnished that it is the same with either.

OF THE SECONDARY AND TERTIARY ROCKS AND STRATA.

22. These being, with few exceptions, of mechanical origin, require no particular description. They are: First—*Limestones*, which are generally constituted either in part or altogether of the *exuviæ of shell-fish*. Secondly—*Sand;* and thirdly—*Clay*. They are of very different degrees of induration, being sometimes consolidated into very hard and compact rocks, whilst in other cases they are loose earthy aggregates. In these formations it is not the mineral character so much as the position they occupy in the crust of the earth, and the organic remains they embrace, that is the object of attention. If the red-sandstone of our vicinity be referred to the transition class, the secondary and tertiary strata of North Carolina (the alluvions of our rivers excepted) are confined to the low country.

OF THE OVERLYING AND VOLCANIC ROCKS.

23. In some parts of the world this is an important class, but as they occupy only a very limited space in our own country, our notice of them will be brief. It is well known that volcanoes pour out from their summits or their sides, a mass of melted matter which flows over the adjacent country and covers it with a bed of rock, sometimes compact, but more frequently more or less cellular, called *lava*. But besides proper lava, there is a considerable number of substances, some of them apparently very ancient, occupying like it an unconformable and overlying position upon the surface of the other strata, and so connected with it by a series of intervening rocks, that it is not doubted that they too have issued in a melted state from the interior of the earth. These rocks remain to be described.

All the varieties of overlying rock are found resting on recent secondary formations, than which they of course are more recent. They are called trap rocks, from the Swedish "trappa," signifying a stair. This name (which is not, however, applied by geologists with any great degree of precision) was given them with reference to the disposition many of them exhibit to assume a columnar shape and to divide into steps, forming natural terraces. The trap rocks often occur in veins, the intersection of which proves that there has been more than one formation of some or all of the varieties. They all consist of a paste, most commonly of the nature of feldspar, but sometimes of indurated clay, or of a substance intermediate between these two, coloured by hornblende or angite disseminated through its whole mass, or containing imbedded crystals of one of these substances, or of feldspar, constituting in the latter case a porphyry.

1. When the rock does not differ essentially in its composition from feldspar, and is but slightly discoloured by foreign ingredients, having a gray and glassy aspect, it is called Trachyte. It abounds in the southern part of France and along the whole chain of the Andes. The summit of Chimborazo is formed altogether of this rock.

2. When the rock has a granular structure and the feldspar is flesh coloured, and contains imbedded crystals of hornblende, it is proper syenite. But if there be a considerable admixture of the ingredients of syenite communicating to the mass a dark colour, it takes the name of greenstone, and if they be very intimately blended, it is called basalt.

8. A basalt containing almond shaped cavities filled with some foreign substance, as limestone or chalcedony, is amygdaloid or toadstone.

4. When an uniform homogeneous base has small crystals of feldsdar imbedded in it in considerable numbers, it becomes *porphyry*, which is not however confined to the overlying rocks, but sometimes alternates with clay-slate. Porphyry abounds

along the Cordillera of the Andes, and in Mexico, where it is rich in the ores of the precious metals. Some varieties are extremely hard. Such was that which was quarried and wrought by the ancient Egyptians, and which being of a reddish or purple colour, gave a name (Πορφυρίτης from Πορφυρα, the shell-fish yielding the purple dye) to the rocks having this constitution.

We have some varieties of flinty slate in our transition formation that are porphyritic, but the only rocks in North Carolina that have any claim to belong to the class of which we are now treating, are the greenstone dykes that traverse the old-red-sandstone and the natural walls in Rowan. Connected with the old-red-sandstone formation there are in the northern states immense masses, rising sometimes into considerable mountains, of basaltic greenstone, which are supposed by geologists to be of volcanic origin, though no one pretends to tell how they gained the position they now occupy. The same substance presents itself in the sandstone of North Carolina, not swelling into such large masses, but forming dykes of a few yards in breadth or hills of moderate elevation.

The natural walls in Rowan have been several times described. A French naturalist, well known in the scientific world by an able work on the insects of Africa, and another on a family of cryptogamous plants, (M. Palisot de Beauvois) passing from the country of the Creeks to Pennsylvania, heard at Salisbury of the natural wall, and wishing to know more of so singular an object, visited it and carried specimens of it to Paris. These were put into the hands of the ablest French mineralogists, M. M. Broignart, Brochant, and Gilet Laumont, who all decided that these stones had at least all the characters of basalt, though they hesitated about pronouncing them to be that substance by reason of their being found in the heart of a primitive country. Such walls or dykes are met with, though not in the same geological connexion, in other parts of the world. There is one that traverses the coal fields in the north of England for many miles. But McCulloch remarks respecting one variety of granite that it is undistinguishable from basalt, though it is connected with and passes into granite of the most common character. Whether the natural walls of Rowan are basaltic dykes or contemporaneous granite veins, there is perhaps room for doubt.

INFLUENCE OF THE ROCKS UPON THE FERTILITY OF THE SOILS PRODUCED BY THEM.

24. It is in connexion with the art and science of agriculture that the strata of the earth exhibit their most interesting relations. Man depends for his existence upon the power possessed by vegetables of attracting the elements (carbon, oxygen, hydrogen and nitrogen) of which they are constituted, combining them so as to form vegetable matter, and incorporating them with their own sub-

stance. If they were to lose this power, or the air and earth, the capacity of furnishing these elements, all living things would die; first the brute creation, but our own race would not evade the general ruin. The inhabitants of the ocean as well as of the land, the lower as well as the higher orders of living beings are nourished either directly or indirectly by vegetable matter. That shell fish do not thrive upon a bed of pure siliceous sand, is known to accurate observers, who frequent the borders of the sea, nor would they be able to exist at all but for the supply of vegetable or animal matter that is brought to them dissolved or suspended in the water of the ocean that flows over them.

A very few vegetables are proper air plants, that is, require only some solid body to which to apply themselves, or a fibrous substance, such as moss, cotton, or amianthus, amongst which to insinuate their roots, and they will thrive and grow without being brought into contact with either earth or water. The Tillandsia Usneoides or long moss of the Low-Country, is an example. But in general, we know that trees and plants require the presence of soil into which to strike their roots, as also that to those which are most valuable by reason of their affording food or clothing, or otherwise subserving the convenience or necessity of man or other animals, a soil of a peculiar kind is necesary, or they fail of attaining the highest perfection of size and quality of which they are capable.

Under the action of the elements the rocky strata of the globe are undergoing disintegration and decay. Some merely crumble down into a coarse gravel, whilst others are resolved at once into an impalpable powder. It is by the disintegration of the rocks that arable land has been produced in all quarters of the world. Is there any connexion between the structure and composition of the rocks and the fertility of the soils they form? There is a very evident connexion of this kind. *Why* the relations should be such as are observed in nature we are unable to tell; why for instance the valley of Egypt should be more productive than the neighbouring sands of Lybia, or the low-ground alluvions of our large rivers, than the pine barrens by which they are skirted on either hand. We can only generalize those facts which experience and observation have well ascertained.

The fertility of different soils so far as it depends upon their own constitution and the character of the rocks from which they have been formed, is determined by four principal circumstances.

1. Their composition; the kind of earth of which the rocks are made up.

2. Their susceptibility of disintegration by the action of the elements.

3. The nature of their upper surface, whether level, or rugged, and broken.

4. The amount of decayed vegetable or animal matter the soil in question may contain.

Of these four concurrent causes of productiveness or sterility, the last has little connexion with the science of Geology. The influence of the others will be stated in accordance with what has been observed in other countries, and is laid down in the books; after this we may enquire how far these representations agree with the facts that may be observed in regard to the soil of North Carolina.

25. *Composition.* The simple minerals constituting the crust of the globe are composed almost exclusively of four kinds of earth; silica, alumina, lime and magnesia, combined with each other in different proportions. It is therefore of these four earths that soils are formed in every part of the world. They contain besides, a little iron, and a minute quantity of the rarer earths and metallic oxides, but these are not abundant enough to affect in any considerable degree their fertility.

So far is magnesia from increasing the fertility of the soil, that it may be doubted whether its influence is not positively injurious to all the forms of vegetable life. Thus the occurrence of soapstone rocks, which owe their peculiar character to the presence of this earth, is always marked by sterility and barrenness in their neighbourhood. Of the other earths, no one will by itself form a good soil. Vegetables will not grow in a pure siliceous sand, whether coarse or fine. Some require a larger admixture of alumina than others. The long leaved pine (pinus australis of Michaux) will thrive where corn will not grow; but even this becomes dwarfish, if the sand predominate so as nearly to exclude the clay. If on the other hand the alumina pass a certain limit, a clay so close and dense is formed, and so liable to change with every change of the weather, acquiring almost the hardness of a baked brick in a dry season, and becoming so overcharged with moisture in a wet one, that vegetables will not thrive in it. The chalk formation in England and France furnishes evidence that limestone does not by itself produce a good soil.

It is by a proper mixture of these earths and of a certain quantity of decayed vegetable matter, all in a state of minute division, that a soil of the highest possible degree of fertility is created. Silica and alumina combined in proper proportions, will of themselves form good land, but the addition of a little lime increases greatly its productiveness. Hence arises the fertility of some of the western states. The counties about Lexington in Kentucky, are not surpassed in this respect (some river bottoms excepted) by any part of the world, nor resting as they do upon a foundation of limestone, is there reason to apprehend that they will be exhausted by constant tillage. The influence of a quantity of lime upon the productiveness of a soil, is well exhibited in two small tracts, in the low-country of North Carolina; the Rich-lands of Onslow, and that bearing the name of Rocky-point, on the north-east branch of the Cape Fear, in New Hanover. A bed of shell limestone, which underlies this part of the state, here rises to the surface and aiding by its decomposition in the formation of the soil, communicates to it a very high degree of fertility.

2. *Susceptibility of Disintegration and Surface.*—A wide difference in their susceptibility of disintegration, is observed amongst rocks bearing the same name. Some varieties of granite lose their consistency and are converted to a great depth into a mass of coarse gravel, whilst others undergo but inconsiderable changes, though exposed to the action of the weather for ages. This rock is supposed to be attacked by destroying agents, through the medium of the potassa entering into the composition of its feldspar. It is not always the softest rock that is the most liable to decay. Soapstone, though so soft as to be easily cut with a knife, is amongst the most indestructible of the rocks. When a rock formation, by reason either of its composition or of the manner in which its integrant particles are united, is not affected by those causes which change the aspect and condition of other portions of the earth's crust, it is evident that it may fail for many ages of covering itself with such a coating of soil as is adequate to the demands of agriculture; as also that if its surface be mountainous and broken, the soil may be carried away by the rain as rapidly as it is formed. The susceptibility of disintegration, and surface, of the strata have therefore an influence, but incomparably less in most cases than their composition, upon the fertility of the soils they form.

1. The primitive rocks are said to produce by their decomposition a soil of very moderate fertility. Granite is also stated to be inferior in regard to the soil it forms to gneiss, and gneiss to mica slate. In many cases all three of the circumstances upon which the formation of a good soil depends, are wanting in this class. Silica often predominates in their composition, so that there is not a due proportion of alumina; it is seldom that they contain any lime, their disintegration proceeds slowly, and occupying as they do the crests of mountains, they are liable to be washed away as soon as the attraction of cohesion that united their particles, is destroyed. They abound in pure springs of excellent water, and with few exceptions are occupied by a vigorous and healthy though sparse population.

A large part of the good land in North Carolina has been produced by the decomposition of primitive rocks. The *most ancient* primitive formation, extending along the bases of the western mountains and to a considerable distance east of them, has good land on the banks of the creeks and rivers, but the largest bodies of soil susceptible of cultivation, have proceeded from a formation of recent primitive rocks, stretching through the middle counties, and the tracts where hornblende predominates in their composition, as in Cabarrus and Mecklenberg, are in general superior to the rest.

2. The transition rocks being composed of particles that are not associated in the close and intimate union produced by chemi-

cal attraction, are said to be more susceptible of disintegration than the primitive. They also more frequently contain lime. Where this earth is present, the fertility of the soil created, will depend upon the relative proportion of the other ingredients of the rock. Thus a gray-wacke containing lime, and in which the argillaceous cement is abundant, will form good land. But where, as in the case of the sandstone lying east of us, the rock is an aggregate of particles of silica, held together by a cement without lime and small in quantity, the soil arising from its decomposition, will be light and unproductive. Clay-slate is said to form a tough strong soil, which retains whatever it receives; but in North Carolina it is only where a rock considerably removed from pure argillite is found, that there is good land within the limits of the transition formation.

3. The secondary and tertiary strata, having only a moderate degree of consolidation, and a position very often approaching to the horizontal, the character of the soils proceeding from them, will depend almost exclusively upon their composition. The fertility of the alluvions of rivers, is to be ascribed in a considerable degree to the fact of their being highly charged with decayed animal and vegetable matter, but the relative proportion and fineness of their component earths, are to be regarded as important concurrent causes.

OF METALLIC VEINS AND BEDS OF VALUABLE MINERALS.

26. There is another subject connected with the rock formations of the earth, which awakens in the minds of many persons, even a livelier interest than the one to which we have just been attending. It is that of metallic veins and mineral beds embracing valuable ores and other fossils, in relation to which a number of facts of a miscellaneous character, and not admitting of much classification or reference to general principles, are to be stated.

The mineral substances that are sought after with so much eagerness, by reason either of their important applications in the arts or the exchangeable value in commerce which immemorial usage has conferred upon them, occur in four different varieties of circumstance and situation.

1. In veins traversing other rocks.
2. In beds between two contiguous strata.
3. Disseminated through a whole rocky mass.
4. In situations into which they have been transported from their original repositories by running water.

The valuable metals, whether native or combined with a mineralizer, are generally obtained from veins or from such situations that there is reason to believe they were originally derived from them. Manganese and iron frequently, and some of the other metals rarely, occur in beds. The whole mass of a rock, containing a metallic ore thickly disseminated through it, is sometimes raised and worked under the name of ore. The gneiss and mica slate rocks, enveloping crystals of magnetic oxide of iron, of the western counties of North Carolina, are an example. We shall treat first, and at greatest length, of veins.

It appears that the strata constituting the crust of the globe, have been fractured since their consolidation, the sides of the fissure separated from each other, and the vacant space filled with a foreign substance, sometimes enveloping a quantity of metallic ore, and in that case called a vein. The whole mass of the vein must have been either, poured into the fissure from above, forced into it from below, or transferred into the position in which it is found by agents and methods of which we have no accurate knowledge. Circumstances to be noticed hereafter, prove that in most cases at least, veins cannot be coeval with the rocks they traverse. When the substance occupying the fissure is stone or clay, it is called a dyke, of which the natural walls of Rowan are perhaps examples. Werner defined a vein to be "*the mineral contents of a vertical or inclined fissure, nearly straight, and of indefinite length and depth.*"

The thickness of veins varies from the fraction of an inch to many feet. It is not uniform throughout the whole extent of the same vein, but increases or diminishes, both laterally, and as the vein descends into the earth. The great vein of silver ore at Guanaxuato, in Mexico, which has yielded a larger amount of that metal than any other that has been explored by man, is twenty-two feet across at the surface, and much more at a considerable depth. There is no instance on record, where a vein has been wrought to the bottom and exhausted, though the quantity of ore has sometimes become so small as to cause it to be abandoned. It is probable that in many cases of this kind, the mine would become richer at a greater depth, as the productiveness of every vein is continually varying. Veins cut through the strata and descend into the earth, at an angle with the plane of the horizon, which is different in different mines, but always considerable. It is sometimes a right angle. If at any time they appear to occupy a bed between contiguous strata, they may commonly be traced to a vein nearly or quite perpendicular to those strata, with which they are connected, and of which they appear to be branches. Amongst the workmen, the perpendicular, or such as descend at a large angle are called rake veins, and the horizontal, or such as follow the direction of the strata, flat veins. In England the large and productive veins most commonly run east and west, and it has been thought that there is a tendency to the same direction in other parts of the world. The principal vein of the most valuable of the North Carolina gold mines, (Capps'), does not vay much from the meridian, and descends into the earth at an angle of about seventy-five degrees. Such at least, were the indications at the surface, and when it was first opened.

Veins are often separated from the rock they intersect, by a thin wall or lining of clay or some other mineral. Sometimes the ore extends in a compact mass from one side of the fissure to the other, but more commonly it is imbedded in a matrix, gangue, or vein-stone, or forms layers alternating with it, suggesting the idea of their having been deposited in succession upon the sides of the fissure, until the cavity was at length filled. The gangue is occasionally of the same nature with the lining of the vein just mentioned ; it is always different from the rock it traverses. Quartz, carbonate, and fluate, of lime, and sulphate of baryta, are the most common substances. Two or more of these, or varieties of the same substance of different colour or texture, are found associated in the same vein, and applied in successive layers, some of which contain ore, whilst others are barren. In the North Carolina gold mines, the gangue is cellular quartz. Veins undergo many changes as they descend, and this relates not only to their productiveness, but sometimes also to the kind of ore they yield. There are veins in Cornwall, which yield tin at the surface and afterwards prove rich in copper.

When two veins, or a vein and a dyke cross each other, as not unfrequently happens, the working of the vein brings to light the appearances attendant on such an intersection. On cutting through the dyke, the continuation of the vein is not found in the line of its former direction, but elevated considerably above or depressed below, or shifted to the right hand or the left, of its former course. These shiftings of the strata are called by the workmen faults, and are commonly regarded as proving that when the crust of the earth was ruptured, and the sides of the fracture separated, it was done with great violence so as to derange and displace the strata to a great extent. Sometimes, veins cross each other without any change in the direction or appearance of either, or of the rocky strata in which they are both included.

27. Werner supposed that all veins and dykes were produced by the shrinking of the materials of which the mountains are composed, and the subsequent introduction of the substances constituting the vein, in a state of solution, from above. That fissures in the crust of the earth have sometimes been so filled, is probable from the fact that they contain substances that have apparently been washed in from the surface, such as rounded stones and undecayed vegetable matter, but that the materials of metallic veins have not been thus poured in, in a state of solution, from above, is rendered certain by all we know respecting the properties of those substances, and their distribution through the crust of the earth. There is no form of matter known to us that would act as the common solvent of all the contents of many veins—of the quartz and the sulphurets of copper, lead, and zinc, for example, of the lead mines at Southampton, in Massachusetts, even though we suppose it capable of dissolving one of them. The greater part of the metallic ores occur onlyin veins, whereas, had they

been spread out in a liquid state over the surface of the earth, and thus placed in a condition to enter and occupy the fissures in which they now appear, large collections of them would have been formed by reason of their high specific gravity, in those basin-shaped cavities which occur frequently in every country, and in which nevertheless we never find them. Indeed, nothing can be more crude and preposterous than the theory of Werner, in regard to the formation of veins.

The theory of Hutton, which represents them as produced by the consolidation of the material of which they are composed, forced in a state of fusion into fissures, previously existing in the strata, by a force operating from below, though appearing at first less encumbered with difficulties, has but little the advantage of its rival. This violent and tumultuous entrance of the materials of the vein, is totally inconsistent with that perfection of crystallization which is often witnessed in the different substances associated in its composition. In the Southampton mine, just referred to, the sulphuret of lead instead of being scattered in shapeless masses, through the whole extent of the gangue, is collected into large and well defined crystals, perfectly distinct from the quartz in which they are imbedded. That where a vein passes through two or more strata of different composition and character, its width and productiveness vary along with the rock in which it lies, is another fact that is calculated to render the soundness of this theory doubtful, even if it should not be regarded as altogether fatal to it. Of the examples that have been noticed and recorded of this kind of dependence, two only will be cited.

1. In the north of England there is a body of stratified rocks that is rich in the ores of lead. It is divided into fifty-five distinct beds, exhibiting three principal varieties of composition and structure Nine of these beds are limestone, eighteen siliceous sandstone, and the rest shale, with thin beds of imperfect coal. The different kinds alternate with each other. The veins traverse them all, and have been worked more or less in all of them, but the ore is found abundantly only in particular beds. When the veins pass through the shales, they yield very little, if any, ore; in the sandstone they are more productive—are richer still in the limestone, but it is a single bed called the *great limestone*, that has yielded four-fifths of all the metal drawn from the veins of this distict.

2. A vein of quartz traversing argillite in the north-western part of Montgomery county in North Carolina, was found to be rich in gold. The owner (Barringer) with the assistance of his family, obtained from it six pounds of gold, worth about sixteen hundred dollars in the day after it was discovered. But the argillite here forms only a superficial covering on the top of another rock. As soon as the vein passes from this into the subjacent stratum, magnesian limestone takes the place of the quartz, and it ceases to be auriferous. Other examples might be cited especi-

ally from the tin and copper mines of Cornwall, of the dependence of veins in regard to their productiveness, and the kind of ore they yield, upon the character of the including rock.

The formation of veins must evidently have been less sudden, tumultuous, and mechanical than it has been represented. Neither simple solution nor simple fusion, with subsequent precipitation or crystallization, will account for the appearances. Nor is sublimation from an interior source of heat, which has also been proposed as the cause by which they may have been produced, less liable to objection. None of these hypotheses account for the influence of the including rock, upon the richness and other characters of the vein by which it is traversed.

When we look through nature for an agent, competent to the production of the effects we are considering, that whose modes of operation and the laws by which they are regulated, are the objects of the science of Galvanism, presents itself as having the best claim to a fulfilment of the required conditions. It is now but fifty years since its existence was first suspected, and our knowledge of its powers is still limited. It has been ascertained, however, that matter is transferred by it from one point of space to another, without any clear indications at the time, of the changes that are going on, and that subjected to its influence, one chemical element is made to traverse another for which it has a strong affinity, without any combination. It is also excited and brought into action by the application to each other, of surfaces of different nature and constitution, such as the strata that constitute the crust of the earth are—and according as these differed from each other in composition or magnitude, it was to be expected that the accumulations would be directed on some points in preference to others. If galvanic electricity be the agent by which veins have been formed, we may refer to it all the different kinds, whether earthy, metalliferous, contemporaneous, or of date subsequent to that of the rocks in which they lie.

DISTRIBUTION OF METALLIC VEINS AND MINERAL BEDS THROUGH THE STRATA.

28. Is the distribution of metallic veins and of valuable minerals of every kind through the strata of the globe, regulated by any general laws, or is every kind of ore or other fossil found indiscriminately in every formation from the oldest to the most recent? Some statements in relation to this subject were introduced into our account of the rocks, which it may be useful to recapitulate in connection with a few additional remarks in this place.

1. Metallic veins are confined to the primitive, transition, and the lowest, or most ancient of the secondary rocks. The cause, whatever it was, which operated in their production, had ceased

to act, before the newer secondary strata had begun to be deposited. It would, therefore, be great folly to look for them in the low-country of North Carolina. It is improbable that we shall discover in that part of the state the ore of any metal but iron, or that it contains more than two or three species of iron ore.

2. Salt, coal, and gypsum, have never yet been found, except in the transition, secondary, and tertiary strata. The valuable mines of these substances, and especially of coal, are in the newer transition and ancient secondary. They do not, therefore, exist in our western counties.

3. A difference obtains amongst the different strata, embracing metallic veins, in regard both to the *kind* of metal they yield, and the *quantity*, when the ores of the same metal are common to two or more species of rock, as will appear from the following more particular statements.

4. A greater *variety* of metallic ores is found in granite than in any other rock: a circumstance to be attributed in part to the fact that no other substance occupies so large a space on the surface of the globe, but the quantity of metal derived from veins traversing granite, is generally small. The most important mines wrought in it are those of tin and iron. The more valuable of the gold mines of North Carolina are in a granitic country, though the veins do not appear to traverse this rock but another, embedded in it, or reposing upon it.

5. *Gneiss* abounds in ores, which are in veins and beds. Mines of tin, lead, copper, zinc, silver, and cobalt, are wrought in it.—Some of the iron mines of North Carolina yielding the best kind of ore are in gneiss.

6. *Mica Slate* contains nearly the same metals that are found in gneiss, and in about the same abundance.

7. *Quartz Rock* is not known to contain any valuable ores of any kind.

8. *Serpentine* is distinguished for the presence of magnetic iron ore, often occuring in octahedral crystals. It yields also the chromate of iron.

9. *Primitive Limestone* embraces veins and beds of iron, lead, and zinc.

10. *Clay Slate*, (including under this single denomination porphyry and grey-wacke), is rich in the metals, containing beds and veins of most of the more valuable kinds. It abounds especially in the ores of copper, lead, and silver.

11. Tin, bismuth, chromium, molybdenum, titanium, cerium, columbium, and uranium, (with the exception of the first three, rare and worthless substances), belong to the older primitive rocks, only very feeble traces of them being found amongst the newer formations.

12. Arsenic, cobalt, nickel, silver, and copper, are found in the ancient primitive formations, but are not confined to them, some of them being abundant in rocks of later date.

13. Gold, tellurium, antimony, and manganese, extend from the newer primitive to the older secondary.

14. Lead, zinc, cadmium, and mercury, though sometimes found (especially lead) in the older rocks, appear to be the most recent of the metals, occurring in the greatest quantity in the later transition formations.

15. Iron is found in every rock, from the oldest gneiss or granite to the most recent alluvial deposit.

16. A number of different metals are frequently associated, or occur in considerable quantities at moderate distances, within the limits of the same mining district. The tin, copper, lead, gold, silver, iron, bismuth, zinc, antimony, cobalt, arsenic, tungsten, titanium, nickel, manganese, and molybdenum (16), of Cornwall—the silver, iron, arsenic, copper, lead, zinc, gold, tin, quicksilver, antimony, and manganese, (11), of the great silver mine at Guanaxuato, in Mexico—the gold, silver, copper, lead, arsenic, and iron, of the mining region of North Carolina, are examples.

17. A rock of a given character will be eminently metalliferous in one country, and in another where its apparent age, structure, composition, and other characters are much the same, it will be almost without the trace of a metal. The gneiss of Saxony is rich, that of Scotland is poor. This diversity we are unable to account for. From the general aspect of a country, therefore, we can form only some very loose conjectures respecting its rocks, whether they will be metalliferous or not.

29. The foregoing statements comprise the principal facts that have been ascertained, respecting mineral veins and beds in general. They relate especially, to the primitive, transition, and older secondary rocks, to which, as has been remarked, metallic veins are confined. Three substances of great importance and value, either in the domestic economy of mankind or in various arts and manufactures, are found in greatest abundance amongst the secondary strata, the geological position of which, and the circumstances under which they occur, will be stated somewhat at length, both because the subject is interesting in itself, and because the facts to be noticed afford some insight into the ancient condition of the earth, and enable us to comprehend the nature of the revolutions to which it has been subjected. The substances referred to, are fossil salt, gypsum, and coal, with which last, iron ore is often associated.

For the study of the secondary strata, no country whose geology has been hitherto investigated, offers as many advantages as England. Nearly the whole of the south-eastern and midland counties are underlain or constituted of formations belonging to this period, disposed in successive beds one over the other in a conformable position and dipping very gently towards the south-east. The space they occupy on the earth's surface, is not so large as to make it difficult to trace and mark the boundaries of each stratum, and compare its remote parts, with reference, either to their composition or to their imbedded organic remains. The extent, thickness, and composition of these strata have been investigated by able geologists. The names they bear, are in part, such as having been first applied to them by miners or the inhabitants of the districts through which they pass, have since been adopted by the men of science devoted to these studies.

Beginning with the uppermost and omitting some sub-divisions, there are the crag, London-clay, plastic-clay and sand, upper-chalk, lower-chalk, chalk-marl, green-sand, weald-clay, iron-sand, Portland limestone, Kimmeridge-clay, coral rag, calcareous grit, Oxford or clunch-clay, cornbrash and forest marble, great oolite, inferior oolite, lias, new-red-sandstone, magnesian limestone, the coal measures, millstone grit and shale, carboniferous or mountain limestone, old-red-sandstone.

This long catalogue of uncouth names, shows at least, the minute accuracy with which the whole subject has been studied, and the extent to which the division of the strata has been carried. If we pass over to the continent of Europe, and compare the geological structure of France, the Netherlands, and Germany, with that of England, we find a general correspondence, but with important points of difference. Some formations are persistent, retaining the same characters over large tracts; others are widely distributed, but liable to vary. What is a body of loose sand, or a soft and friable sandstone in England, (green-sand) in the Alps of Savoy, becomes a hard, blackish, compact limestone, proved to belong to the same epoch with the other, only by the circumstance of their containing imbedded in them the same organic remains. Some strata are confined within narrow limits, to a single county, province, or department; or to a part of it, and in their place, there come in amongst those of the adjacent regions, one, two, three, or more *equivalent* formations as they are called, of which, their geological position shews that they are of nearly the same age, but which bear little resemblance to each other in any particular. The characters of these deposits are such, as to admit of their being distributed into a few families or groups, according to the following plan, where the corresponding strata of England, France, and Germany are ranged opposite to each other in parallel columns.

Tertiary system.	Crag, London Clay, Plastic Clay & Sand.	Strata of the Paris Basin.	Strata of the Basin of Vienna.
Cretaceous system.	Chalk, Chalk Marl, Green Sand, Weald Clay, Iron Sand.	Craie, Craie Tufau, Glauconie Crayeuse, Glauconie Sableuse.	Kreide, Planerkalk.

Oolitic system.	Portland Limestone, Kimmeridge Clay, Coral Rag, Oxford Clay, Cornbrash, Forest Marble, Great Oolite, Fuller's earth beds, Inferior Oolite.	Calcaire de Jura.	Jurakalk.
Lias.	Upper Lias shale, Lias Marlstone, Lower Lias clay and shale, Lias Rock.	Calcaire-à Gryphites, Gres.	Quadersandstein, Keuper.
Saliferous system.	New-red Sandstone, Magnesian Limestone, Exeter Red Conglomerate.	Marnes Irisées, Gres Bigarré, Gres des Vosges, Calcaire Penéen.	Muschelkalk, Bunter Sandstein, Rogenstein, Zechstein, Rothe-todte-liegende.
Carboniferous system.	The Coal Measures, Carboniferous or Mountain Limestone, Old Red Sandstone.	Terrain Houiller, Calcaire Carbonifere, Vieux Grès rouge ou Psammite rougeatre.	

30. In England, one of these beds, and but one, embraces masses of fossil salt and gypsum. They are all deposits from water. There has, therefore, been a time, and it has occurred but once, when the waters standing over certain parts of the island of Great Britian were so strongly impregnated with salt, that enough to supply the kingdom with that substance for a very long period, was collected into a single stratum called the new or variegated sandstone. Brine springs rise out of it, and in their neighborhood, plants, whose natural habitat is the sea-shore, are found many miles in the interior.

These springs were known as early as when the Romans had possession of the island, and the water was evaporated to obtain salt, in which the soldiers received a part of their pay. The salt made from them is purer than that procured from the water of the ocean, containing none of the salts of magnesia, along with the chloride of sodium. The evaporation of the brine was an important and lucrative business in the time of Elizabeth. The strata from which they issue, were at length bored into, at Northwich, in Cheshire, in the hope of finding coal, and the enterprise resulted in the discovery of a bed of salt, some of which is very nearly pure. Below this, and separated from it by a layer of clay, another was afterwards found, into which the principal workings have been carried. No very accurate knowledge of the magnitude of these saline deposits has been obtained, but according to the best authorities, they may extend over an area of about one-square mile, and be about three hundred feet in thickness, but they thin off at the edges, having the form, not of beds, but of lenticular masses. The annual produce of this mine is about 300,000 tons; the larger part of which is carried down the river Weaver, and shipped from Liverpool. Upwards of three millions of bushels were sent from England to the United States, in the year 1831, but the whole of this was not from Northwich. There are other beds or masses in the same county, where salt is manufactured by the evaporation of the brine. The new-red-sandstone also embraces beds of gypsum, large quantities of which are raised for the supply of various arts and manufactures in different parts of the formation.

31. The same minerals (salt and gypsum) are found associated in other countries and regions of the globe, imbedded in a rock of similar composition and structure, and as was once supposed by geologists, of the same age with the new-red-sandstone of the English strata. Our limits will admit only of a notice of the more remarkable beds of fossil salt on the eastern continent, and of the brine springs of our own country.

1. At Cardona, in the south-eastern part of Spain, is a small mountain composed of alternating layers of gypsum and salt. The area of its base is a little more than a square mile, and its height between three hundred and three hundred and fifty feet. It was at one time stated to be a primitive, then a transition formation, next referred to the new-red-sandstone, and is now said by Lyell, to be contemporaneous with the chalk.

2. Salt springs abound in the department of Meurthe, in the eastern part of France. In the year 1819, the strata from which they rise, were bored into, as in England, with the view of finding coal. Coal was not found, but instead it, beds of salt and gypsum, extending through an area of two hundred and seventy square miles. Four different beds of salt have been met with, the third of which is forty-five feet in thickness. The depth to which the fourth descends has not been ascertained. Corresponding beds have been proved by boring on the opposite side of the Rhine, in Baden and Wirtemburg, but nothing is known respecting their number, extent, and thickness; the saturated brine being here employed, instead of the solid material of the beds in procuring salt. All these are in formations which are the equivalents of the new-red-sandstone, and which are also known to furnish gypsum and salt springs in France and Spain, as well as in other parts of Europe.

3. The salt mines of Wieliczka, in Poland, have been long celebrated. They were discovered in 1251 and though they have now been wrought for nearly six hundred years, there are no indications that they are likely to be exhausted. The country about Wieliczka, like the rest of Poland, is covered by tertiary deposits, beneath which, the saliferous strata of that country, as

well as others along the bases of the Carpathian mountains, were supposed to lie, and to correspond in age to those of France and England, but Boué represents them as belonging to the tertiary period.

4. "When it is known," says Dr. Kidd, in his Geological Essays, "that rock salt is used as a building stone, at Ormus, "and that the sand of the great desert of Persia, is of a brick-red "colour, and that salt abounds throughout that desert, there can "be little doubt in the mind of a geologist, that the 'Rock-marl,' "(new-red-sandstone) 'formation' abounds in that part of the "world." Fossil salt is more common, and is found in larger quantities in central Asia, than in Europe.

5. Herodotus says that in some parts of Lybia, as well as in Arabia, the dwellings of the inhabitants are constructed of salt. It is from this quarter, (the desert of Sahara), that central Africa, especially the fertile and populous region drained by the Niger, is supplied with this important article. Shaw describes the extensive rock-salt formations of El Jerred, a part of the great Sahara, as a solid mountain of a reddish purple color.

6. Salt springs rise out the red-sandstone formation of Nova Scotia, which furnishes the very great quantity of gypsum that is imported every year into the United States from that province. About 700,000 bushels of salt were manufactured annually, some years since, from the water of salt springs, in the State of New York. The rock from which the water issues, is described by Eaton, as "An aggregate of minute rounded grains of quartzose sand, or of minute argillaceous and quartzose grains, formed into a red or greenish sandstone, or soft, red or greenish, brittle, clay slate." In the western part of Virginia, in Tennessee, Kentucky, Ohio, Illinois, Missouri, Arkansaw, and indeed throughout the whole basin of the Mississippi and its tributary streams, brine springs occur at moderate intervals, but they appear to be more numerous on its western than on its eastern side. About the time of the purchase of that territory by the United States, an immense body of fossil salt, constituting a mountain range, was supposed to exist in Upper Louisiana—the desert tract between the States of Missouri and Arkansaw, and the Rocky Mountains. The exploring expedition sent by the General Government into that region, has rendered it doubtful whether there are any beds of fossil salt in that part of the United States; though it is certain that if there are none, the whole body of the sandstone must be highly charged with salt, as brine springs abound there.

"The whole country, near the mountains," says Dr. James, "abounds in licks, brine springs and saline efflorescences, but it is "in the neighborhood of the red-sand-rock, that salt is met with "in the greatest abundance and purity. The immediate valley of "the Canadian river, in the upper part of its course, varies in "width, from a few rods to three or four miles, but it is almost "invariably bounded by precipices of red-sand-rock, forming "the river bluffs. In the valley between these, incrustations of "nearly pure salt are often found covering the surface to a great "extent in the manner of thin ice, and causing it to appear "when seen at a distance, as if covered with snow." "The Canadian, like Red River," says Mr. Nuttall, "always continues red and muddy, and is often impotably saline." Wherever there are salt springs within the limits of the United States, the rocks in the neighbourhood are sandstone, clay, or limestone with organic remains, and in many cases they embrace beds of gypsum. Fossil salt abounds also in Mexico, and South America.

The saliferous sandstones furnish another example of that too hasty generalization which has so often marked the history whilst it has arrested for a time, the progress of geology. There is a general agreement in the composition, structure, and aspect of these rocks. They contain imbedded masses of salt and gypsum. It was inferred that they are of the same age, and were produced by the operation of the same causes in all parts of the world. But when even such as are not very remote from each other, and are supposed to be nearly contemporaneous, are carefully compared, wide discrepancies appear. Those of England are confined to a single stratum or formation which hardly admits of a subdivision, and in which organic remains, if they occur, are very rare. In France and Germany they extend through at least three different strata, the keuper, muschelkalk, and bunter-sandstein of the German geologists, of which the last only has an intimate agreement with the new-red-sandstone, and the second, abounding in organic remains, is regarded by Brogniart as the proper repository of the salt. When the test furnished by the imbedded remains is applied to them, the saliferous strata of Spain, France, and Poland are seen to separate widely, proving that the causes which have operated in the formation of these deposits of salt and gypsum, have been repeatedly active upon the surface of the globe, and in places and at epochs far remote from each other. In the state of New York the beds affording these minerals, are separated by three intervening strata.

32. Next below the new-red-sandstone is the magnesian or conglomerate limestone. To this succeeds in some parts of England, another red-sandstone, supposed to be the equivalent of the Rothe-liegende, and next to this are the coal measures, the independent coal formation of Werner. This embraces, with two or three very unimportant exceptions, all the seams of workable coal that exist on the Island of Great Britain. Of course it furnishes nineteen-twentieths of the fuel consumed for domestic purposes, by the population of the country: keeps two hundred and fifty-three *iron* furnaces of gigantic dimensions, besides innumerable smaller ones, employed in other metallurgic operations, in blast, from one year's end to another: puts thousands of steam engines in motion, and contributes more than any other one thing to the wealth and

strength of the kingdom. To an inhabitant of Great Britain, therefore, this subject must be far more interesting than to ourselves; yet if we take any pleasure in studying the circumstances upon which the wealth of nations depends, and investigating the causes by which their prosperity is promoted, it will not be without attractions for persons born and bred on the western side of the Atlantic.

Coal, using the word in a sense a little different from that in which it is generally received, for *mineral carbon*, under whatever form it appears, is sparingly distributed through all the formations, from the most ancient primitive, quite up to the most recent alluvion. The black lead of Wake county and other parts of North Carolina, is an example of carbon in a primitive rock. At the other extremity of the scale is the substance bearing the name of lignite, (fossil wood) still retaining its fibrous texture very perfectly in some places, and in others approaching as nearly to coal, that is found imbedded in the clay and sand of the low-country, one of the most recent of the tertiary strata. If a quantity of fallen leaves be carried down by one of our rivers and deposited in some arm or bay, setting out from the stream, where the water is still, and a layer of sand and gravel be afterwards thrown out upon this vegetable mass, it will constitute a coal-field in miniature. Time will be required for the chemical affinities to exert themselves, but with time, it will be converted as it is believed that all the varieties of coal have already been converted, into a substance, fitted for the purposes either of manufacturing industry or domestic economy.

Peat is a kind of fuel that is now in the act of being formed, especially in the higher latitudes, in all parts of the world. It consists of the remains of ancient forests, covered over with beds of moss and sometimes simply of the moss itself, almost to the exclusion of everything else. Layer after layer in succession springs up, comes to maturity, decays, and dies, leaving the vegetable matter that entered into its composition, and especially the carbon, upon the spot where it grew. A thick bed is at length formed, the upper part of which is made up of the roots and stems of the sphagnum; (which is the kind of moss that flourishes most in such situations as are favourable to the formation of peat); the middle is much altered by the action of the water, and the bottom is converted into what is nearly related to coal.

33. All the strata mentioned in the enumeration heretofore made, as forming together the south-eastern part of the island of Great Britian exhibit thin seams of coal, but except in the single formation to which our attention is now directed, they are not worth working—are mere objects of geological curiosity. But the mineral wealth of the coal measures makes ample compensation for the poverty of the other strata.

They consist of a series of alternating beds of coal, slate clay, and sandstone, the alternations being frequently and indefinitely repeated.

There are two principal kinds of coal, 1. *anthracite*, which is found in Kilkenny county, (Ireland), in some parts of Wales, and in immense quantities in the State of Pennsylvania. It is composed principally of carbon with a portion of earthy matter and water. It burns with very little of either smoke or flame. 2. *bituminous coal*, which is the kind raised from most of the British coal fields. This, besides the carbon which is its principal constituent, contains both hydrogen and nitrogen. Of the manner in which these elements are combined or associated, we have little accurate knowledge. It has been supposed that the hydrogen is united to a part of the carbon, forming bitumen, which exists in the mass of the coal. In consequence of the volatility of the bitumen, this kind yields a flame when it is burnt, and some sorts more than others. Newcastle coal undergoes a kind of fusion, by which the separate pieces are united into one mass, when it feels the influence of the heat, from which it is called caking coal.—Other varieties from other localities have this quality imperfectly or not at all.

All the beds of coal, slate clay, and sandstone, taken together form a stratum, which in Northumberland, is three thousand feet, or more than half a mile in thickness. The thickness, however, varies greatly in different places, and this is probably the greatest that occurs throughout the whole extent of the formation. About twenty feet of it only are made up of seams of workable coal, but these seams extend over an area of one hundred and eighty square miles. It is from this quarter that London and all the eastern and the southern part of England, as far west as Plymouth, are supplied with fuel, and a demand is created for an annual excavation of about three millions of cubic yards. The beds of this field are eighty-two in number. Twenty-five are beds of coal, generally too thin to be worked, and fifty-seven, sandstone, and slate clay. The two most important coal seams are the *high main* and *low main*; the former four hundred and fifty feet below the surface, and six feet thick; the latter three hundred and sixty feet deeper, and six feet three inches thick. The main seam in the Dudley and Birmingham coal field is thirty feet in thickness.

The coal formation has been spoken of hitherto as a single stratum, separating the more ancient from the more recent beds, and it might be supposed that it extends quite through the island. But this is by no means the case. It consists of a number of separate deposits, which are probably of about the same age, though they do not very intimately resemble each other; occupying irregular, basin-shaped cavities, scattered through the central and western parts of the kingdom. The most extensive and important, are those of Northumberland, of the West Riding of Yorkshire, of Lancashire, of Stafford and Warwickshires, of South Wales, and in Scotland, that which extends across the island from the opening of the Frith of Forth, in a south-westerly direction, and within which the cities of Edinburg and Glasgow are included.

33. The ancient Britons and Romans must have been acquainted with coal as an inflammable substance, it being sometimes found at the surface, especially in the bottoms of ravines and the beds of rivers. But the whole country being shaded like our own by interminable forests, no use was made of it for fuel. It has been an article of commerce for seven hundred years. It is believed by those who have paid particular attention to the subject, that the mines will continue to supply the wants of the country at the present rate of demand for some centuries to come. Yet it is certain that they must eventually be exhausted, and the formation in which they are, be stripped altogether of its mineral treasures, and as there is no other carboniferous stratum to which recourse may be had, the people of England must be driven back to the use of wood for fuel. The effects of such an event upon the populousness, wealth, and strength of the country, it requires no great amount of penetration to foresee. Its approach would be greatly retarded if some method could be devised of extracting the whole contents of the coal fields, and making them available either in domestic economy or the processes of manufacture; but at present from a quarter to a half, and in some mines as much as two-thirds of the whole amount of coal they contain, is either left behind or expended and wasted in different ways in bringing the rest to the surface. Nor does it appear that this immense loss can be very materially diminished. Massive pillars of coal must necessarily be left untouched in every mine to support the superincumbent strata, and prevent them from sinking down and crushing the workmen—and although these are afterwards wrought out and raised to the surface, the coal they yield is obtained with much additional labour, danger, and loss.

That the coal fields have not had too much importance attributed to them, in determining the present condition of the British Empire will be conceded when it is remarked that the seats of all the important manufactures are either within the limits of the coal formations or on their borders, and that they draw from them the principal element of their activity. The steam engine, the machinery employed in the spinning of cotton and wool, and more recently of flax, that which is an important auxiliary in the manufacture of earthen and hardware, and cutlery, would all become, in a great measure, useless and unavailable, if the supply of coal for the creation of steam were to be exhausted. The mines of copper, tin, and lead would be abandoned from the impossibility of draining them, as would those of iron, when the ores could no longer be smelted, and those of salt when there was no fuel for the evaporation of the brine. The principal reason why Great Britain is able to maintain the position she has gained and defy competition in the market of the civilized world for the products of art and manufacture, is, that she can at a cheap rate bring the untiring powers and agencies of nature to contend with human strength. Steam does for her, what in other parts of the world is accomplished by animal muscle and sinew. The following is the value in round numbers of the principal products of British industry, taken from McCulloch, the price of the raw material being included.

Cotton Manufacture,	$150,000,000.	Iron Manufacture, - - -	$25,000,000.
Woollen, " - -	100,000,000.	Copper, tin, lead, salt, -	12,000,000.
Hardware, " - - -	76,000,000.	Earthenware, " - - -	10,000,000.
Linen, " - -	36,000,000.	Glass, " - - -	8,000,000.

The great seat of the manufacture of cotton, is on the Lancashire coal field at Manchester, and in the region north of it; of wool, in the West Riding of Yorkshire, in a district about ten miles in diameter, lying south-west of Leeds; of cutlery, at Sheffield, on the same coal field; of earthenware, in the northern part of Staffordshire, near Newcastle under line, where there is an abundant supply of excellent coal; of salt in Cheshire, which is surrounded by coal fields; of hardware, exclusive of cutlery, at Birmingham, the toy-shop of Europe, close by the rich deposits of South Staffordshire—which deposits as well as those of South Wales, afford immense quantities of iron lying imbedded in layers in the strata of slate clay accompanying the coal, and there being a plenty of limestone in the immediate neighbourhood, all the materials for the manufacture of iron are found in close proximity, whilst they are easy of access. The iron used in the construction of the rail roads of the United States is made either in Staffordshire or in South Wales. Coal for the steam engines used in draining the mines of Cornwall, is carried from Wales, and the vessels are laden on their return with copper ore, the most of which is smelted at Swansea. Glass is made in various places, but always in the coal region. The linen manufacture has flourished most in the north of Ireland, which is well supplied with fuel from Lancashire and Scotland. The part of Scotland lying about Glasgow, is outstripping every other in wealth and population. At Leeds, coal sells for $1.78 per ton, at Sheffield for $1.67, in Staffordshire at from $2.00 to 2.67 for the best kind; Schuylkill coal in New York at $6.50, and at the mine for $2.25. Whilst the ancient towns of Canterbury, Winchester, and Salisbury, in the South of England, have remained nearly stationary; those which have been mentioned as the principal seats of these different manufactures, have increased rapidly in size and importance.

Few parts of the world at present known, if any, are as abundantly supplied with coal as the British Islands; and perhaps there is no country upon whose strength and wealth, extensive mines of this substance could have so decisive an influence. The coldness of the climate demands a great annual consumption of fuel for domestic purposes: if we except the northern part of Scotland, there are no where, extensive mountain tracts, incapable of cultivation, to be devoted to its growth. It abounds in the metallic ores, especially in the ores of iron, in the smelting of which, mineral coal has been for many years most advantageously applied, whilst the smallness of the superficial contents of these islands, compared with that of their rival states and kingdoms, on the continent, requires a dense population, deriving its subsistence in part from abroad in exchange for manufactures, to enable them to maintain the place they have long held in the scale of nations, and to the successful prosecution of almost every kind of manufacture, a plentiful supply of fuel is altogether necessary. The facilities for water carriage afforded by the seas by which they are surrounded, and the rivers and canals by which they are traversed, favour greatly the transportation of the coal, to every part of the country. It is unpleasant to feel that we are drawing from stores of an indispensable material, whose riches are limited, which can never be replenished, and which must therefore eventually be exhausted; but it would be unreasonable in a Briton to resign himself to melancholy, in view of the final degradation that awaits his country, as it is supposed that the present expenditure may continue for a thousand years longer, before the use of coal for fuel must be abandoned.

34. The coal fields of France are much smaller and less numerous than those of England. They are distributed through an elevated, central, and primitive plateau, lying on the west side of the Rhone, between the latitudes of 44° and 47°, amongst the head waters of the Loire and Garonne. The northernmost is in the department of Nievre, the most southern in that of Gard. The largest and most valuable is that of St. Etienne, in the department of Loire, extending over an area of eighty-seven square miles. This furnishes nearly half of the coal that is raised annually in France. A coal formation extends across Belgium, from near Aix-la-Chapelle, in a south-westerly direction by Liege, Namur, Charleroi and Mons, to the neighbourhood of Valenciennes, within the border of France. East of this, beds of the same mineral are found in Saxony, Bohemia and Hungary. Italy has no coal. It is known to exist in Asia Minor, Syria, India, China, Japan, New Holland, Van Dieman's Land, and in some parts of Africa.

Beds of coal are rare in that part of the United States lying east of the Blue Ridge. Anthracite is found at Worcester in Massachusetts, and in considerable quantity in Rhode Island; bituminous coal in Virginia, fourteen miles west of Richmond, and on the banks of Deep River, Chatham Co. in North Carolina. The Virginia coal field occupies a trough in the primary rocks, thirty-five miles in length, and eight miles across at the widest point. The principal body of the coal lies at the bottom, and along the sides of the trough, either in contact with the subjacent rock, or separated from it by a layer of shale a couple of feet in thickness. It crops out, therefore, along the edges of the field. A few feet above, are one or more seams of coal, superimposed upon which, are from five hundred to one thousand feet of sandstone. The original floor of the mine appears to have been very uneven, and the coal to have been collected into the hollows before the sand was brought over it, so that the thickness of the seam or bed of coal, varies from a few inches, to forty or fifty feet.

But the principal coal fields of the United States are amongst the ridges of the Alleghany Mountains, and on the west side of them, especially in Pennsylvania, which appears to abound beyond every other part of our country in this mineral. The great anthracite formations of Pennsylvania are on the eastern side of the Susquehanna river, on the head waters of the Schuylkill and Lehigh, and also on both sides and beneath the bed of the Lackawanna, and of the Susquehanna, where it traverses the Wyoming valley. For the number and thickness of the beds, there is no parallel on the eastern continent. At Mauch-Chunk, on the Lehigh, the coal mine is an open quarry, exhibiting on its sides, precipices of solid coal, from twelve to thirty-five feet in height. Bituminous coal abounds in the western part of Pennsylvania, especially about Pittsburg, and is found in a number of other places in the Valley of the Mississippi,—in Ohio, Kentucky, Tennessee, Alabama, but the fact only of its existence has been ascertained, very little being known about the number, thickness or extent of the beds. There is probably no country in the world that will compare with Pennsylvania in the number, extent, and riches of its coal-fields, a circumstance that is destined at a future day, to have an important influence upon the relative power and standing of that state amongst the members of this confederacy.

The shales and sandstones accompanying coal, present impressions of vegetables, and other appearances, which have induced a general belief amongst geologists, that the beds of this mineral, in all parts of the world, have proceeded from the decomposition of vegetables, bearing little resemblance in form, or the manner of their growth, to such as now occupy the soil of the same countries.

THEORETICAL GEOLOGY.—INTRODUCTORY.

35. From documents that have descended to us from other ages, we draw up an account of the most important and remarkable of the transactions of men, and call it a history of the world. This record of the events of other times is carefully studied, and the names of the great men of Greece and Italy, are as familiar to us as those of our intimate friends and acquaintance. We require minute accuracy in the account given of the causes by which the rise, advancement, and decay of empires has been produced and promoted, even when no lesson of wisdom or virtue can be drawn from the change, and the only object in view, is the gratification of an enlightened curiosity.

May we not be permitted to devote a few pages to the history of the earth itself, of the revolutions it has undergone, and by which it has been brought into the condition in which we now behold it. It is not states and empires alone that have been torn by intestine commotions. The evidence is ample, that the solid fabric of the globe has been shaken and rent. The history of these changes is brief; it is written on the stony strata of the earth. But if the events recorded are few in number, they are attractive from their magnificence.

In no department of science is an acute, but sober and cautious judgment more necessary, than in decyphering these ancient records. Every character from which valuable information can be derived must be passed under review, and the instruction elicited which it is capable of conveying. At the same time we must be on our guard, and see that fancy does not get the mastery over the judgment, lest we find in the present appearances of the globe, evidences of changes that have never occurred, and of which no indications can be discovered by any eye but ours.

The nature of the danger, and also of the investigations upon which we are about to enter, may be illustrated by an example. It is well known that on the banks of the Nile are various fabrics, especially temples, and tombs of colossal dimensions, some of which stand upon the surface of the soil, and others are excavated in the rocks under ground. The material of which they are formed varies with the geological character of the district in which they are. In the southern, or upper end of the valley of Egypt, they are hewn out of granite, lower down they are executed in sandstone, and finally we come to the pyramids, built as has been already stated, of secondary limestone. One must have been upon the spot if he would have an accurate idea of the vastness and solidity of these ancient structures. Their walls are covered with hieroglyphics. Of the language of the people by whom these works were executed, we know next to nothing. If they had historians, their works have perished, so that it is from "lying Greece," that we have derived the little we profess to know respecting them. But we will suppose the light shed by Grecian literature upon the antiquities of Egypt, to be extinguished, and that under these circumstances, an intelligent traveller passing under the portico of an Egyptian temple, should wish to know something of the character, condition, and fortunes of the people by whom it was built; there are a few particulars, respecting which he would be able to arrive at a good degree of certainty.

He would not, for instance, doubt that there once existed along the banks of the Nile, a numerous, industrious and flourishing people, united for a long time under one government. They must have been numerous and industrious, or they never would have been able to execute such stupendous works. They must have been united under one government, because a number of little independent states, would never have combined for the erection of so many costly structures, and have adhered to their engagements until they were completed. The unity of design observable in these temples, taken in connexion with the time, that at the shortest must have been consumed in finishing them, proves that a particular scheme was formed at the beginning, and long pursued.

The greater part of the edifices, affording evidence from their plan and decorations, that they were devoted to the services of religion, it would appear very probable that the body in whom the supreme control of affairs was vested, was a despotic priesthood. It seems, besides, scarcely possible, that anything short of a dread of the anger of heaven, perpetually instilled by such a body of men, could procure the sacrifice of so vast an amount of human labour, for an object not immediately and visibly connected with the personal enjoyment of the individuals by whom it was performed.

From the skill and science that must have been employed in cutting, transporting, and raising such immense masses of stone, it must be further evident, that this ancient people had arrived at a considerable degree of advancement in civilization and the arts.

So long as he confined himself to inferences, such as these, when speaking of the ancient Egyptians, our traveller would be treading on safe ground; but if from the scanty materials furnished on the spot, he should pretend to specify the particular methods by which that ancient people was consolidated, and why it flourished and fell, he would be forsaking the path of the inductive philosophy, and invading the field of the epic poet. In the science of Geology we are safe, so long as we confine ourselves to legitimate inferences from well established facts, and state what has happened, rather than the particular manner in which it was accomplished; but when without interrogating nature we begin to state with precise accuracy, how the earth may have been formed, or its strata in the first instance deposited, and afterwards brought into the positions in which we find them, we fall into the errors of Hutton and Werner. The investigation of the *causes* of change, is not, however, to be neglected in the history of the earth any more than in that of man, and we are led, therefore, to notice the two principal agents by which the various revolutions to which our planet has been subjected, are supposed to have been produced.

HUTTON'S THEORY.

36. It has already appeared that of the various kinds of rock, some exhibit a crystalline structure, and the greater part a considerable degree of hardness. But we know of no examples of crystallization and consolidation, except from a state of fluidity. A heap of sand or of any dry powder, will remain for ages without exhibiting any tendency to unite into a solid body. We infer, therefore, that the crystalline rocks must have been in a fluid, and a part of the earthy ones also in a fluid, or the whole in a semifluid state. But the only two agents which are capable of bringing them into that state, are heat and moisture, fire and

water. By the application of a heat sufficiently intense, earthy bodies are fused. On cooling they harden, and if the refrigeration be very slow, many of them will exhibit more or less of a crystalline structure. If immersed in water they are dissolved to some extent, or if they are in fine powder they remain suspended in the water, and when this is evaporated, consolidation and crystallization takes place as before. Werner, as we have seen, attributed the great changes the earth has undergone to the agency of *water*. Hutton allowed that water had been active in producing changes upon the surface of the globe, but with him the great efficient agent that gave the rocks their structure and form, was *fire*.

Hutton first remarked, that the mountains and hills are continually wasted by the action of the elements. Their highest peaks are abraded by storms, the finer particles are carried to a distance by the torrents that rush down their sides, and the larger deposited at their bases. This process will continue to go on, until the whole mass of the existing continents shall have been carried down to the ocean, over the bottom of which the earthy matter will, by the rolling of the waves and the currents that prevail there, be distributed.

In this situation the mineral beds will be fused, and elevated by the action of an internal fire. What is now the bottom of the sea will become dry land, and the waves will roll over countries that have once been the dwelling place of men. Such revolutions Hutton asserted have more than once changed the face of the globe, and that they will be indefinitely repeated hereafter.

The Wernerians objected to these doctrines, the existence of carbonate of lime amongst all classes of rocks. This substance is converted into quicklime, by the escape of its carbonic acid when strongly heated. Sir James Hall, the intimate friend of Hutton, undertook to relieve his theory from a part of the difficulties under which it laboured, by exposing carbonate of lime and other substances to heat *under pressure*, for it was under pressure—weighed down by an immense superincumbent load, that the existing mountains were fused and consolidated. He found that in such circumstances carbonate of lime may be fused and made to assume a crystalline structure, without parting with its acid, and that the appearance of various substances is very different, as after having been intensely heated they are rapidly or slowly cooled.

There was further objected to Hutton, the immense number of ages it must take to wear down the largest mountain ranges formed of very refractory and imperishable materials. In some favourable situations the disintegration of the rocks proceeds rapidly, but in others the progress of the work is inconceivably slow. The pillars and statuary of the Parthenon at Athens, have lost hardly any of the sharpness of the angles produced by the original chiseling, after a lapse of more than two thousand years. The graves of the aborignal Britons still exhibit themselves, rising distinctly above the surface of the ground, though thrown up before the time of Cæsar's invasion. The objection was held to be a valid and strong one, though as Hutton set no limit to the time during which the revolutions he supposed the earth to be undergoing, and to have undergone, are accomplished, his partizans would not allow it the weight to which it seemed to be entitled.

A more powerful and decisive objection to the theory of Hutton was found in the absence of positive evidence of its truth, so that when philosophers were called upon to embrace it, they held it to be enough to demand in return the *proof* of the existence of that central fire, by which the mineral beds constituting the bottom of the sea were to be fused, and the mountains thrown up, and that it would operate in the way and produce the effects ascribed to it. Of the two rival theories—those of Hutton and Werner, neither is at present held in the form under which it was proposed by its author; but there has unquestionably been a tendency in the progress of geological discovery and doctrine, to approach that of Hutton, rather than the other.

CAUSES OF GEOLOGICAL CHANGES.

37. Before entering upon the subject of theoretical geology, it will be necessary to turn our attention to the agents that are now modifying the surface of the globe, and enquire what are their modes of action, and what the nature and extent of the effects they produce. We shall thus be prepared to judge whether the ancient revolutions of the earth bore any intimate resemblance to the changes that are proceeding before our eyes, so that we may safely attribute the formation of the primitive, transition, and secondary strata to the operation of causes that are now active, or we are compelled to assume the existence of agents that have now disappeared from the face of the globe—or whether again supposing the agents the same we must assign to them a strength and activity in the most ancient times, very far superior to what is exerted by them now. It has been represented that the earth as at present, and has been (with a single exception) since the era of the creation of man, in a state of *comparative* repose, the convulsions to which it has been subjected since that event, as well as the changes now in progress, being inconsiderable when compared with those of earlier date. A contrary opinion has been advanced and advocated with great ability within the last few years—that the amount of geological action and change is much the same from age to age: that the ranges of high mountains which traverse the surface of the globe, have not been produced by a few violent convulsions, but are the final result of an accumulation of effects each in itself inconsiderable, and requiring together myriads of ages for their accomplishment. Whichever of these opinions we embrace, a knowledge of the present will be

of value, and assist us in explaining the past. The causes of geological phenomena, now in active operation, are the following:

38. 1.—*The atmosphere; including the different substances accidentally mixed with it, and the agents by which its own condition and its effects upon the other forms of matter are modified.*

There is good reason to believe that much of the surface of the existing continents where it comes into contact with the atmosphere, was originally a solid rock, which by the combined action of the air, of heat, cold, moisture, and the mechanical force of violent storms, has been gradually disintegrated and converted into soil. The amount of effect produced upon the rocks by these destroying agents, depends upon their position, form, and structure, as well as their composition. The progress of these changes in the trap rocks is a subject of considerable interest, by reason of its furnishing data, from which to calculate without certain limits, the time when the existence of a given mass upon the surface of the earth commenced, and the number of the ages, therefore, during which the part of the earth's surface immediately about it, has remained pretty nearly in the condition in which we now behold it.

These rocks often present themselves under the form of mountain ranges of considerable elevation and many miles in length, with mural precipices on one side, and sometimes on both sides. They are traversed by rents and fissures in different directions, which subjects them, especially in high latitudes, to a pretty rapid disintegration. Rain water insinuates itself into their crevices, and being congealed and expanded there, fragments of considerable size are torn off, and accumulated around the base of the precipice, forming at length a considerable mass reposing in a sloping position against the side of the mountain. What is here stated as true of the trap is found to obtain in a greater or less degree in other rock formations.

Of the rapidity with which the process is going on, we are able to judge with a considerable degree of accuracy from what occurs from year to year, and presuming that the rate of disintegration has been in all ages pretty nearly the same, we may evidently calculate within certain limits, the time when the mountain assumed its form, and exhibited a perpendicular face from top to bottom.

Loose sands are in some parts of the world raised by the winds out of their bed, and driven onwards over fertile fields which are buried up and consigned to sterility and desolation. Thus a considerable portion of ancient Egypt, a soil once occupied by a very dense population, has been long since buried under the sands of the great Lybian desert. Similar effects, but on a more limited scale, have been produced in that part of the kingdom of France, which lies along the bay of Biscay, and at a few points on the Atlantic coast of the United States.

2. *Rivers; which act upon their own beds, and also carry down to the sea the finer particles of earth that are washed into them from the hills amongst which they flow.*

The rocks and stones in the beds of all streams that flow with any considerable degree of rapidity, are tumbled by the current upon each other, and gradually diminished in size and worn into a round form by the attrition they undergo. All streams are rendered turbid by earthy matter, brought in by water that has fallen in rain upon the tract drained by them, at some season of the year The fine sand and clay they hold suspended are deposited at their mouths, forming a Delta or body of alluvial ground, which is periodically extended, and with a considerable degree of uniformity. The progress of these changes is matter of observation and history. "Many cities," says Cuvier, "which were flourishing sea-ports in well known periods of history, are now several leagues inland, and several have even been ruined by this change." We learn from Strabo that Ravenna stood among lagunes, in the time of Augustus, as Venice does now; but Ravenna is now at the distance of a league from the sea. Adria, which gave name to the Adriatic, was somewhat more than twenty centuries ago the chief port of that sea, from which it is now at the distance of eighteen miles. The whole of the north-western border of the Adriatic, where it receives the streams that flow down from the Alps, through an extent of one hundred miles, and from two to twenty miles in breadth has been gained from the sea, and converted into a low marsh within the last two thousand years. The cities, Rosetta and Foah, built originally at the points where the lower branches of the Nile join the Mediterranean, afford the same evidence of the extension of the land, being now at some distance from the sea. The Delta of the Ganges and Burrampooter, extends two hundred miles along the coast, and not less than two hundred and twenty into the interior. That of the Mississippi is constantly advancing into the Gulf of Mexico.

In the formation of a Delta, the sediment is thrown down first and most abundantly at the mouth, and on the immediate bank of the stream, and a long narrow ridge is created, the middle of which is occupied throughout its length by the river channel. The declivity of the plane along which the water flows, being diminished by an increase in its length, whilst its altitude remains the same; the sediment is also accumulated at the bottom, which is thus raised, and the stream may be described as running upon a ridge, with a tendency becoming constantly greater to pass its banks and deluge the country on either hand. The Mississippi exhibits these results in the lower part of its course. The ridge formed by its alluvion is about three miles in width, including the stream, and twenty-four feet high; but as the river is from one hundred to one hundred and sixty feet deep, its bottom is far below the general level of the country and below the level of the sea. It is to this ridge that the plantations near the river, both above and below New Orleans are confined. It is evident that after having observed the rate of yearly increase, and traced the alluvial formation up to the point where it commenced, we have, as in the case of the trap rocks, the data necessary for calculating, though not with any very great degree of accuracy, the time when it began to be created.

In some countries, springs rise out of the earth charged with carbonate of lime, which they hold dissolved by means of the carbonic acid they contain, and others are impregnated silica. These substances they deposit, commonly at no great distance from the fountain head. The travertino of the Roman states, extensively used as a building stone, and the incrustations about the hot springs of Iceland and the Azores, are examples of such formations.

3. *The sea; which in some parts of the world is rapidly undermining the coasts of the continent, and in others throwing up long ranges of sand banks.*

Where it is the former process that is going on; the earth that falls down when the under-stratum that supported it is removed, is first accumulated around the base of the cliff. Afterwards the influx and efflux of the tide spreads this mass over the bottom of the adjacent sea, till at length a bank is formed which curbs the fury of the waves, and prevents any farther encroachment. But when a current sweeping over the spot carries off the materials of the cliff as they fall, the work of destruction goes on indefinitely. The sea is in this way making inroads upon the land at a great number of points on the eastern coast of England.

In the other case the flood tide brings in a quantity of mud and sand, which the succeeding ebb does not carry away, and a long line of banks is sometimes formed at a distance from the ancient boundary of land and water. It is in this way, according to some geologists, that the whole low country of the United States has been thrown up.

4. *A very diminutive race of animals—the Zoophytes which inhabit the various kinds of coral and madrepore, are forming islands in the mid-ocean, and reefs and shelves along the coasts of the continents.*

The Red Sea, the Persian Gulf, the Indian Ocean and that part of the Pacific lying within the latitude of thirty degrees on both sides of the equator, are amongst the well known theatres of their operations; the activity and amount of which, however, appear to have been over-rated. Thus the harbours of the Red Sea, upon the excellence of which, as well as upon the safety of the navigation of the sea itself, the commercial prosperity of Ancient Egypt depended, have been represented as entirely choaked up by reefs of coral that have been created in later times, and are still increasing in extent. But the ruin of these harbours is now said to have been produced by the accumulation of sand and other causes.

Most of the low islands of the Pacific are supposed to own their existence to the labours of the Zoophytes. A generation of these animalcules, planted by means that are unknown to us, occupies with a colony a certain extent of surface; probably the tops of a mountain at the bottom of the sea—in some cases at least, the circular edge of the crater of a submarine volcano. After having lived out the natural term of its existence it perishes, leaving its habitations behind. The material of which they are built is carbonate of lime, with a very small quantity of animal matter associated with it. On the top of the layer of coral thus produced, a second generation comes into being, and shares the fate of its predecessor. Others succeed, until at length an immense column is raised in the sea, its top being larger than its base, and its height from fifty to one hundred feet. When they have brought this product of their labours to the level of low water mark, new generations cease to be produced upon its top. To be constantly covered with water seems to be indispensable to their existence. "But "the sand, pieces of coral, and other broken fragments thrown up "by the sea, adhere to the rock and form a solid mass upon it as "high as the common tides reach. That elevation surpassed, "the future remnants being rarely covered, lose their adhesive "property, and remaining in a loose state, form what is usually "called a key upon the top of the reef. The new bank is not "long in being visited by sea birds, salt plants take root upon it, "and a soil begins to be formed; a cocoa-nut or the drupe of a pan-"danus is thrown on shore; land birds visit it and deposit the seeds "of shrubs and trees; every high tide, and still more every gale, "adds something to the bank, the form of an island is gradually "assumed, and last of all comes man to take possession."

And a wet uncomfortable time he would have of it unquestionably. The case furnishes another example of those rash inferences from premises which do not warrant the conclusions that are drawn from them, which are unfortunately not yet altogether banished from the science of geology. It is very evident that the waves cannot, unaided and alone, throw up an island over which they will not continue to break during every violent storm.

It is quite certain that the coral reefs traversing those seas, have been created in the manner supposed. It is further certain that before becoming the habitation and dwelling place of man, they must, in all cases, have been placed beyond the reach of the waves; either by a depression of the general level of the ocean, or by being lifted out of its bed by a force acting from below. And after having studied the effects of volcanic action in other parts of the globe, we shall become satisfied that it has in all cases been conjoined with the labours of the Zoophytes in the production of the coral islands of the Pacific.

39.—5. *The cause of volcanoes and earthquakes, which, as they are now regarded as having a common origin, will be treated of under the same common title.*

Of the five causes of geological phenomena now in active operation, this will require by far the most careful and extended consideration, for two reasons. First; because the changes produced by it in the crust of the earth within the period to which history ascends, are by no means inconsiderable, and secondly, because the evidence is constantly accumulating of its having been the principal agent in the production of the existing continents, and communicating to the earth the most remarkable features by which its exterior surface is distinguished.

A volcano is an opening made by subterraneous fire in the outer crust of the earth, through which are ejected, vapour, smoke, and stones, with streams of melted rock called lava. Some volcanoes throw out boiling water and mud.

At the instant of its formation, every volcano appears to have been simply an *opening* in the crust of the earth; but the stones that are thrown out, being urged onward by a considerable projectile force, and their path declining more or less from a perpendicular, many of them fall at a distance from the orifice through which they issued, so that at first a small hillock and eventually a mountain, sometimes of gigantic dimensions is formed—of which the small ant hills that appear every where in a dry soil in the summer, furnish a good miniature representation. The form of both is the same; a truncated cone with a funnel shaped cavity, scoped out in its top: the inclination of both its interior and exterior surface being such as is just sufficient to prevent a fragment of the material of which the whole pile is built, from rolling to the bottom where it is placed upon the dividing ridge. It may be appropriate to mention also, that an ant hill an inch in height, and having the form of Ætna, would occupy about the same relative space in a field of seven acres, that Ætna does upon the surface of the globe. The whole mass of a volcanic mountain is not, however, in all cases made of materials that have been projected into the air, and afterwards fallen to the earth. The melted lava sometimes rises in the cavity or crater, so as either to fill it to the brim and pour over its top, or after ascending to a certain height finds a passage through its side. In either case, after flowing to a distance determined by the degree of its fluidity, and the surface of the ground near the base of the mountain, it is consolidated into a rock, adding something to the general elevation of the district in which the volcano is situated. Sometimes also it tears away and scatters over the adjacent country one of the sides of the volcanic cone, destroying altogether the symmetry and beauty of its form. The following are the additional facts respecting volcanoes, which may be regarded as more particularly worthy of attention.

1. *The cause of the activity of volcanoes, whatever may be its nature, is extensively distributed through the crust of the globe, since there is no part of it of considerable extent in which they do not occur.*

They are more frequently upon islands than on the continent. Iceland, in the northern Atlantic, has a number of active volcanoes—ten or twelve. Sicily, on the south of Europe, has Ætna, and the kingdom of Naples, Vesuvius. The islands north of Sicily and also the southern islands of the Grecian Archipelago, are volcanic. Morier says, that several mountains in Persia constantly emit smoke. Humboldt supposes himself to have ascertained the existence of a volcanic district in central Tartary. The peninsula of Kamschatka appears to be in a great part the product of volcanic eruptions, and contains a number of active volcanoes, some of them of immense size. The long chain of islands extending from Kamschatka to New Holland, is of a similar character. The Kurile Isles appear to consist of a train of volcanic mountains, of which many are still subject to eruption The Japanese islands contain ten occasionally active vents. The Polynesian Archipelago owes its existence, to a great extent, to volcanic action. The Philippine Islands, the Moluccas, Celebes, Java, Sumatra, New Guinea, the Marianne Isles, one or two of the Friendly Islands, and the Sandwich Islands, may be mentioned especially as the seats of volcanic fires.

Very little is known of the interior of Africa, but most of the islands by which it is surrounded are volcanic. Except on the coast of Greenland, there are no active volcanoes on the eastern side of North America, but they are not wanting on the western side. Capt. Cook saw a volcano in lat. 61°, and two others of immense size a little farther south. These belong to the system extending from Kamschatka along the eastern side of Asia. Five are reported to exist in California. Mexico has five. Three of the West India Islands (St. Vincent, St. Lucia, and Guadaloupe), are active volcanoes; and the long chain of the gigantic Andes would seem to be almost one continued volcano, so numerous are the volcanic peaks. These statements will be sufficient to show the extent to which the causes of the activity of volcanoes are distributed through the crust of the globe.

2. *When these fires have once been kindled in the interior of the earth, they continue to burn for ages, thereby affording evidence that in the particular localities where they exist, the causes of their activity are accumulated to an immense extent.*

The magazine from which Ætna has been supplied for more than two thousand years, is not yet exhausted, and what amount of material that vast furnace is capable of consuming in a single day, (if, as has been supposed, its eruptions are the effect of a real combustion) he will best judge who has been upon the spot, measured with his eye the height of the mountain and the capacity of the crater, and recollected that the latter has sometimes been filled to the brim with liquid matter, so as to overflow. Of the period during which the mountains of Asia, Africa, and America have been volcanoes we know nothing. Mankind appear to have been first civilized around the eastern shores of the Mediteranean. There letters were invented—there first historians provided as is said by the father of history, Ὡς μητε τα γενομενα εξ ανθρωπων τω χρονω εξιτηλα γενηται,—"that the glorious actions performed by illustrious men, should not be forgotten;" and in relating the exploits of *men*, they furnish the earliest accounts that have come down to us (those contained in the sacred scriptures excepted) of the changes that have occurred in the physical world. The only volcanoes, therefore, whose history we can hope to know with any considerable degree of exactness, are those which are near the shores of the Mediteranean.

Ætna is not mentioned as a burning mountain by Homer, and it has thence been inferred that it was not a volcano in his time. But it may have burnt in former ages, and been slumbering in the days of Homer. The same is true of the Lipari Islands. Pindar decribes Ætna as a cauldron of liquid fire; and Thucydides informs us that the eruption which must have given rise to Pindar's allusion, was the second that had occured since the Greeks had settled on the coasts of Sicily.

From the building of Rome till the year 79 after Christ, a period of more than eight centuries, Vesuvius appears to have been in a state of profound repose, as no mention is made of any eruption during the whole of that period; and the ancient writers who refer to this mountain, always speak of its extraordinary beauty and fertility. There were, however, appearances near its summit, which left no doubt of its prior volcanic state, and the cities in its vicinity were paved with the lava of ancient eruptions. Vitruvius, who flourished under Augustus, says that Vesuvius had formerly been burning, and had covered all the adjacent country with its fires. Other classic authors hold similar language respecting it.

The first great eruption on record, took place in the time of Titus, in the year 79, and buried the towns of Herculaneum, Pompeii, and Stabiæ under showers of volcanic sand, stones and scoriæ. After this Vesuvius continued a burning mountain, having eruptions at intervals for more than a thousand years. The fire then seemed to be tending to extinction, as there were but two eruptions in four hundred and ninety-two years, one in 1306, and another which was inconsiderable in 1500. In 1631, woods were growing on the sides of the crater, cattle were pastured there, and it was the haunt of wild animals. For the last two hundred years the eruptions have been frequent. Whilst Vesuvius has experienced these vicissitudes, Stromboli, one of the Lipari Islands, from the time when the earliest notices of it occur on the pages of history, to the present day—though separated from it by an interval of only one hundred and fifty miles, has never ceased to burn.

3. *Volcanoes appear to be less numerous in the crust of the earth at present, than they were in the most ancient times: from whence it follows that the causes of their activity may be either exhausted, or repressed and overcome.*

Although the only burning mountains in Europe, the only ones that have burnt within the memory of man, are in Iceland, about the southern extremity of Italy, and on the Grecian Islands, it is certain that the time has been, when the same phenomena were exhibited in other parts of the continent, between Rome and Florence, and on the northern side of the Po, in Italy; in Hungary, on both sides of the Rhine above Cologne, in the southern part of France, and the eastern part of Spain. The appearances of the mountains in these countries taken in connexion with the nature of the substances lying round their bases, are such as to leave no doubt as to their having once been the seat of volcanic fires. The figure of a volcanic mountain is altogether peculiar as well as the material in most cases of which it is composed. Wherever a mountain is found in the form of a truncated cone, with a basin-shaped cavity upon its top, and beds of lava about its base, we need find no difficulty, although it may never have been known to emit either smoke or flame, in pronouncing respecting its origin. Eminences having this figure and the structure and composition of active volcanoes, occur in the countries mentioned, as well as in other parts of the globe, in places remote from what are now the seats of volcanic action. Where the volcanic form is wanting, the substances lying upon the surface often approach so nearly in their character to lava and the other products of burning mountains, as to warrant the belief that they had a similar origin, and were poured in a melted state from the interior of the earth.

4. *Volcanoes are not dispersed irregularly over the surface of the globe, but arranged in systems or clusters, the members of which are commonly situated along a line either straight or moderately curved, suggesting the idea of their being placed over a rent or fissure in the crust of the earth. Nearly all the known active volcanoes are on islands or in the immediate neighborhood of the sea. Whether the same was once true of such as are now extinct we cannot tell, by reason of the great changes that have taken place, in the relative positions of the land and water.*

5. The following statements will serve to convey a more intimate and accurate knowledge of the nature, modes, and effects of volcanic action.

Volcanoes are found to present three principal sorts of phase or peculiarity of character. 1. Some are remarkably uniform in all the phenomena they exhibit. The amount of their activity is the same, and it is always exerted in the same way. Stromboli is an example of this kind. 2. A second class comprises such as constantly give evidence of their volcanic character by a cloud of smoke resting upon their top, and occasionally burst out with greater violence. 3. Others appear sometimes to be altogether extinct, then rage with great fury for a while and afterwards sink down again into repose. Of the last two classes which are much more common than the first, Ætna and Vesuvius may be cited as tolerable examples. This occasional awakening of the volcanic fires from either partial or absolute repose, is called an eruption.

The great regularity of the volcanic action at Stromboli, together with the comparative minuteness of the scale on which the phenomena are there exhibited, admits of our approaching very near to the centre of activity, and observing the changes that take place. The crater itself is also commanded in such a way by a neighbouring eminence that the spectator can look directly down to its bottom. It is seen to contain a quantity of melted lava at a brilliant white heat, which is continually rising and falling. When at its maximum elevation, one or two enormous bubbles form upon its surface, swell rapidly, and finally explode with a loud detonation. A shower of liquid lava is thrown into the air, which cooling there, falls in the form of scoriæ. The surface of the lava is depressed about twenty feet, but rises again in a few minutes, in consequence of the formation of new bubbles, which explode in the same way. The elastic fluid by the expansion of which the bubbles are created, appears to be simply steam.

There is reason to believe that the nature of volcanic action in other parts of the world, does not differ greatly from what it is at Stromboli; except that in the case of this crater, the lava being constantly in a melted state, it offers but little resistance to the elastic fluid that escapes through it; whereas in other cases its passage is so obstructed as to create the most violent convulsions. It is very evident that the results must be widely different when there is a free communication between the centre of volcanic action and the external air; and where a volcano breaks out for the first time through the solid strata of the globe, or an ancient rent that has been obstructed and obliterated by masses of lava that have partly cooled and become consolidated within it, and partly fallen into it from the neighbouring heights, is opened anew.

The indications of an approaching eruption from a dormant volcano, are, a commencement and gradual increase of smoke from the crater. Tremendous subterranean explosions like the firing of artillery, succeed, with tremors of the earth more or less violent. Often, it is said, the state of the atmosphere assumes a peculiar character, there being in it an unusual closeness, stillness, and pressure. Springs disappear, wells are dried up and there is often a splitting and heaving of the strata in the neighbourhood of the volcano. The eruption generally commences with one tremendous burst, which shakes the moutain to its foundations. Sometimes a large part of the mountain disappears at once, being either blown into the air, or engulfed in an abyss beneath. The beds of lava that have obstructed the vent are broken up by the expansive force of the elastic fluid that is struggling to escape, and projected to a great height above the crater. The steam that rises is collected into a cloud, which overhangs the mountain, and condensed into rain, deluging the circumjacent country. It is highly charged with electricity. Vivid, violent flashes of lightning dart from it, and frequently occasion mischief. The fragments of scoriæ that are thrown into the air, being shattered by their explosion, and fall, and comminuted by their mutual friction, are reduced at length to a fine powder, which mixing with the watery vapour, adds to the blackness of the cloud that overhangs the mountain, and either descends under the form of volcanic ashes upon the neighbouring country, or is carried to a distance by the winds. This substance is most abundant towards the close of the eruption, and frequently collects in large quantities in the crater so as to go far towards filling up and obliterating it. In the meantime the liquid lava urged on by the vapour that is struggling for vent, either boils over the edge of the crater, or finds a passage lower down, through the side of the mountain. All the phenomena become gradually less remarkable and violent, and the eruptions after having continued for a number of weeks or months cease altogether. It is observed that when the lava flows freely the tremors of the earth and the explosions become less frequent.

40. Before proceeding to the *causes* of the phenomena just described, it will be of advantage to notice certain others that are nearly related to them, so far as respects their origin, though they differ widely in their effects. There are strong reasons for believing that volcanoes and earthquakes proceed from a common cause, whose operations are so modified by the diversity of the circumstances under which they occur, as to produce the observed variety of result.

Humboldt giving an account of the earthquake which shook, but without injuring, the city of Cumana, during his visit there, well describes the sensations of the man who feels the earth agitated beneath his feet for the first time.

"From our infancy the idea of certain contrasts, fixes itself in "our minds; water appears to us an element that moves, earth a "motionless and inert mass. These ideas are the effect of daily "experience, they are connected with everything that is trans-"mitted to us by the senses. When a shock is felt—when the "earth is shaken on her old foundations which we had deemed "so stable, one instant is sufficient to destroy long illusions. It "is like awakening from a dream, but a painful awakening. We "feel that we have been deceived by the apparent calm of nature; "we become attentive to the least noise, we mistrust for the first "time asoil on which we had so long placed our foot with con-

"fidence. If the shocks be repeated, if they become frequent "during several successive days, the uncertainty quickly disap- "pears. I did not at this time imagine that after a long abode in "the table lands of Quito, and the coasts of Peru, I should become "almost as familiar with the abrupt movements of the ground, "as we are in Europe with the noise of thunder. We did not "think of rising at night in the city of Quito, when subterraneous "rumblings, (bramidos) which seem always to come from the vol- "cano of Pichincha, announced (two, three and sometimes seven "or eight minutes beforehand) a shock. The carelessness of the "inhabitants who recollect that for three centuries past their city "has not been overwhelmed, communicates itself easily to the "least intrepid traveller."

The immediate forerunner of an earthquake is a loud, harsh, subterranean noise, resembling sometimes that which would be produced by a large number of waggons driven furiously along a rugged pavement, and at other times the explosion of cannon. This is succeeded by that shaking or trembling of the earth, from which the phenomenon derives its name, and by which buildings are overthrown, burying too often the wretched inhabitants in their ruins. Very frequently, however, the noise and shock are simultaneous; and when this is not the case, the interval varies very much, from a few seconds to a few minutes. The agitation does not often last longer than a minute, but is sometimes repeated in very quick succession. The motion is not a gradual uplifting, but vibratory, and so rapid that it is dificult for a person who is standing, to keep his feet. The shock that agitated the city of Cumana, when Humboldt was there, was but a slight one, that did no mischief, yet he tells us that he felt it very strongly, though lying in a hammock, and that his companion, M. Bonpland, who was bending over a table examining plants, was almost thrown upon the floor. An Englishman who was in Lisbon when that city was nearly destroyed by an earthquake on the 1st of November, 1755, relates, that after the first shock he joined a mixed multitude of persons, who had fled to the area in front of one of the churches, and were on their knees imploring the protection of heaven; and that when the second shock came on, it was with difficulty that he could keep upon his knees.

A quay which had just been built on the bank of the Tagus, of rough marble, at a great expence, was swallowed up with the people who had collected upon it as a place of safety, and a great number of boats and small vessels that lay near it, not a vestige of any of which was ever seen afterwards. The water was ascertained to be an hundred fathoms in depth, in the place where it stood. The sea was not less affected than the land. Ships that were sailing on the main ocean off the coast of Portugal, received a shock as though they had struck upon a sand bank or rock. The water retired from the shore, leaving it bare to a considerable distance, and then returning in a wave from twenty to sixty feet in height, flowed over land lying beyond the reach of the highest tides. *In the case of the quay there was an evident subsidence of the land.* Other recent examples of the same effect of earthquakes are recorded at Port Royal, in Jamaica, in the Delta of the Indus, and at Puzzuoli, near Naples. The opposite effect of elevation has been witnessed at Puzzuoli, and on the coast of Chili, near Valparaiso. This double agency of earthquakes in producing a movement both upwards and downwards, is a fact of great importance in the science of geology.

The effects of an earthquake are seldom confined to the spot where the greatest force is exerted. That which destroyed Lisbon was felt to the extremities of the continent of Europe. The movement of the earth in this instance is said to have been undulatory, and the undulation to have travelled at the rate of twenty miles in a minute. Where no shock was experienced the water of springs, lakes, and rivers was strangely affected, becoming turbid and overflowing its banks without any apparent cause. Along the nothern coast of Africa the effects were hardly less disastrous than in Portugal itself.

Having stated some of the more remarkable phenomena of both volcanoes and earthquakes, we are prepared to observe that there is such a connexion between the two that we shall be safe in referring them to the same common cause. It might perhaps be sufficient to state in proof of this that those counties in which there are burning mountains, are beyond all others vexed by earthquakes. Southern Italy and Chili, may be cited as examples. In the province of Calabria, not less than nine hundred and forty-nine distinct shocks were felt in a single year—1783. The Atlantic States being far removed from the seat of any active volcano are seldom visited by these terrible movements of the stony strata of the globe. But we have more direct and positive evidence of the connexion between earthquakes and volcanoes. It has been already stated that an eruption of a volcano, that has been for some time dormant is commonly attended by convulsions in the country around it. It appears farther that there is a subterraneous communication and sympathy not only between different districts of a country contigous to the same volcano, but also between craters that are far distant from each other, so that an eruption in one part of the globe will be attended by disturbances in a region many miles, and sometimes many degrees distant. "The volcano of Pasto in South America, uninterruptedly vomited a high column of smoke during three months of the year 1797, and this column disappeared at the very moment when at the distance of nearly three hundred miles the great earthquake of Riobamba, and the mud eruption of the Moya, killed from thirty to forty thousand Indians. The sudden appearance of a new island, thrown up by volcanic fires, amongst the Azores, on the 30th of January 1811, was the forerunner of those dreadful shocks which further to the west shook almost uninterruptedly from the month of May 1811, to that of

June 1813—first the West India Islands, afterwards the vallies of the Ohio and the Mississippi, and at last the opposite coast of Venezuela. Thirty days after the complete destruction of the town of Caraccas, the eruption of the volcano on the island of St. Vincent took place. At the same moment when this explosion happened, on the 30th of April, a subterranean noise was heard throughout a country of nearly fifty thousand square miles in extent."

OF THE CAUSES OF THE PHENOMENA OF VOLCANOES AND EARTHQUAKES.

41. We come now to the most difficult part of this subject, the task of accounting for the phenomena of volcanoes and earthquakes. How is that heat which fuses the rocks generated in the bowels of the earth, and how does it operate in shaking the solid globe? Werner held that the seat of volcanic fires is the coal formation; a secondary stratum. But the volcanoes of South America, have their seat beneath the primitive rocks. Those of Auvergne, in France, have forced their way through a bed of granite. The showers of red hot stones that are projected from the craters of burning mountains during an eruption, and the cloud highly charged with electricity that overhangs them, render it impossible to approach them when in their highest state of activity, for the purpose of studying attentively and accurately the changes that are going on. Nor does the matter that is thrown out afford us much information. Sulphur either free or in some of its combinations appears to be a constant product of all volcanoes. In the crater of Vesuvius there is the smell of burnt bitumen but not in that of Stromboli. Muriatic acid may also be detected, though not in general in any considerable quantity, in the vapours escaping during an eruption. Silica constitutes about one half of the substance of lava; the rest is alumine, magnesia, lime, and iron.

But the first three substances, sulphur, bitumen, and muriatic acid are present in too small quantity to admit of our attributing to them the tremendous convulsions that accompany intense volcanic action. Carbonic acid is disengaged from the fissures and saturates the water of the springs of a volcanic district, nor does this effect cease for many ages after the fire is extinct. In what quantity it may be given out from the crater during an eruption, has not been ascertained. When Sir Humphrey Davy, ascertained that the bases of the alkalis and earths are metallic, and that they take fire when brought into contact with water, the attention of philosophers was directed to them, as probably the agents by which the phenomena of volcanoes are produced: but their extreme levity is one objection to them, nor does the composition of lava accord with this idea. Silicon does not, like potassium and sodium, decompose water by the abstraction of its oxygen when brought into contact with it. Some geologists appear still to believe that volcanic action is produced by the combustion of some compound of sulphur and silicon, or of the bases of the alkalis and earths. The circumstance that almost all the known active volcanoes are situated near the shores of the sea is supposed to favour the opinion, that water derived from that great reservoir is the agent that determines their activitiy. A part of it is said to be decomposed, its oxygen entering into combination with the metallic base or silicon, whilst the hydrogen uniting with the sulphur passes off under the form of sulphuretted hydrogen. The rest of the water being introduced upon substances already in a state of intense ignition, is said to be converted into vapour and under that form, and at a very elevated temperature to exert the immense explosive force by which fragments of rocks are thrown to a vast height into the air.

Two new theories of volcanic action have been proposed within a few years, one by Mr. Poulett Scrope, secretary of the London Geological Society, and the other by M. Cordier, of the Paris Academy of Sciences. They both start with the assumption that the earth was originally a melted mass, of which the exterior crust has parted with its caloric by radiation, and been thus converted into a rock, whilst the great central portion retains its temperature and is now in a liquid state. The merits of this hypothesis we will presently consider. It is a circumstance somewhat remarkable, that of these two theories, one attributes the phenomena of volcanoes to the gradual heating, and the other to the gradual cooling of that crust of the earth which separates the interior liquid mass from the exterior portion, which has already by parting with its heat been converted into a bed of rock.

Scrope, supposes that the temperature of the central nucleus is gradually propagated to the strata adjacent to it, which consist of the materials of lava holding a quantity of water in a state of intimate combination, to which their fluidity is owing. By receiving an accession of heat from below, the elasticity of the water is so much increased that it separates from the particles of fluid rock or lava, and escapes through the solid strata lying above, overturning them, rending them to pieces and throwing them into the air and thus producing the most terrible of the phenomena of volcanoes and earthquakes. At the same time a quantity of the lava urged onward by the elastic vapour that is struggling to escape is forced out of the aperture already formed. The separation of the steam and flow of the lava continue, until the temperature of the focus of activity is so far diminished by the absorption of caloric during the conversion of the water into vapour, and the liquidity of the lava by parting with the water, on the presence of which that liquidity depends, that the causes tending to maintain the activity of the volcanic action, and those by which it is repressed, are in equilibrium, when the eruption ceases. In his view therefore a volcanic eruption is produced simply by the ebullition of a compound liquid, consisting of water and lava, and somewhat analogous in its constitution therefore, to honey, paste, or mud and water, in which it is well known that ebullition may be excited. Scrope, supposes it to be evident from the appearances presented by the lava of Vesuvius at the instant when it issues from the mountain's side and afterwards, that it is a substance so composed—that it is not actually in a state of fusion but rendered liquid by water, which serves as a vehicle for the earthy particles which remain after its escape. The liquidity of lava is said to be always imperfect, never exceeding that of honey and generally such as to require the exertion of a considerable force to thrust a stick or blunt rod into it. At the instant of its emission it has a brilliant white heat, a considerable quantity of vapour is emitted from it and it consolidates almost instantly. The superficial crust thus formed, cracks and splits in all directions, and fresh vapours escape from the crevices. Scrope states also that there is no evidence of the occurrence of a real combustion in the crater of a volcano ; and that what are commonly described as flames are in fact jets of red hot sand and scoriæ. A further illusion is frequently produced by the brilliant light often given out by reflection, from the cloud, that overhangs the mountain.

Instead of supposing that there is gradual accession of heat to the strata lying just within the consolidated crust of the globe, M. Cordier, represents them as parting with their caloric by slow communication to the beds of rock lying above them ; and eventually by radiation, into the regions of space. The consequence of this refrigeration is, a contraction and diminution of the capacity of the crust or shell, in which the liquid central nucleus is enveloped ; by which a part of the matter of which it is composed, is forced out through a few small openings (somewhat in the way in which we squeeze the juice out of an orange); producing the phenomena of earthquakes and volcanoes.

When two theories are proposed to us at the same time, neither of which has our very hearty approbation, and which are altogether at variance with each other, in regard to the principles on which they are founded; it is sometimes a matter of convenience, that there are two of them, as it will be the less necessary to enter upon a minute examination and discussion of the merits of either. It may be enough to array them in opposition to each other. If, however, we be called upon to state which of the theories just exhibited, is the least liable to objection, and capable of being supported by the strongest arguments, the preference seems due to that of Cordier. Mr. Scrope supposes—the earth to have been originally a melted mass, of which the temperature of the exterior crust was so far depressed, that it was consolidated into a rock, and that this very same crust is now receiving heat from the interior nucleus, by which it is again heated to whiteness. There are, perhaps, no experiments by which the changes here supposed, are proved to be impossible, but they seem hardly necessary. It may be regarded almost as a self-evident truth, that a hot body abandoned to itself, will part with its heat in such a way, that the temperature shall go on diminishing, according to some regular law, from the exterior surface towards the centre, and that every individual particle, wherever it may be situated, will grow constantly colder. If this be a correct statement of the changes that would take place, the theory of Scrope is unquestionably erroneous.

The subject of volcanoes is one, in regard to which future ages are destined to have more accurate knowledge, and more enlightened views than we possess at present. The circumstances which attend an eruption, and the order in which the phenomena succeed each other, are calculated to produce the belief, that volcanic action is the result of chemical changes of some kind taking place within the crust of the earth; different masses of the substances that act upon each other, being from time to time brought into contact, and the combustion in this way renewed and kept up from age to age, but the matter thrown out is not, as we have already seen, of a nature to warrant our adhering very obstinately to this opinion. If this view of the subject shall be deemed inadmissible, and the hypothesis of a central fire embraced, we shall perhaps find no better refuge from the harrassing inquietudes of doubt and scepticism, than in the doctrines of Cordier. Some geologists are inclined to combine the two, and to add to the agencies supposed by them, that of water introduced upon the interior heated mass.

OF THE CHANGES PRODUCED BY VOLCANOES AND EARTHQUAKES.

42.—1. The permanent visible effects produced by volcanoes, consist in an elevation of the surface of the earth around their bases, which is covered with a bed of volcanic ashes and socriæ, or with a sheet of lava; and a change in the altitude or form of the mountain itself, which is their seat.

The ashes that were thrown out from the mountain Tomboro, on the island of Sumbawa, in the East Indies, in April, 1815, were so abundant as to crush the roofs of houses on which they fell, at the distance of forty miles, and westward of Sumatra, the floating mass was two feet in thickness and several miles in extent. The stream of lava that issued from Skaptár Jokul, in Iceland, in 1783, was ninety miles in length, at some points from twelve to fifteen miles in breadth, and one hundred and in narrow defiles, six hundred feet in depth. Vesuvius was reduced in height about eight hundred feet, by the eruption of 1822. Ætna has experienced a similar, though not as great a reduction of its elevation, and been afterwards built up again. The plain of Malpais, in the western part of Mexico, was converted into a volcano (Jorullo) 1600 feet in height, on the night of

September 20th, 1759. In 1772 the cone of Papandayang, one of the loftiest volcanoes on the island of Java fell in; a tract sixteen miles long by six miles broad was swallowed up, and the height of the mountain reduced from nine thousand to about five thousand feet.

2. Until very recently, earthquakes were regarded with that feeling of interest which is awakened by dread and terror, almost exclusively, and held entitled to notice on account of their devastations; the cities laid in ruins and the lives destroyed by them. It is only incidentally that mention is made by the older writers of the permanent changes produced by them in the condition of the earth itself.

In June 1819, the country lying about the mouth of the river Indus was visited by a violent earthquake. The usual effects were seen in the demolition of buildings, especially such as were built of stone, and a tract of considerable extent sunk several feet. The fort and village of Sindru, standing on the eastern branch of the river were so much depressed, that only the tops of the houses and wall were visible above the water that immediately flowed in from the sea. At the same time another tract of fifty miles in length and sixteen in breadth, running past the village at the distance of five and a half miles, was elevated into a ridge about ten feet in height. In November 1822, a shock which agitated the whole of Chili, raised the line of coast, north and south of Valparaiso, through a distance of more than one hundred miles, three or four feet, and in the interior of the country the average amount of elevation appears to have been still greater. The beach of the sea was left bare, and shell fish which adhered to the rocks perished.

HISTORY OF THE EARTH.

43. Prop. I. *The earth was in the beginning a fluid or semifluid mass.*

The earth is not a perfect sphere. Its equatorial exceeds its polar diameter by about twenty-six miles. (Sec. 6.) This is true not only of the terraqueous globe as it exists in oceans, islands and continents, but of the great rocky skeleton of the earth. The surface of the ground in every country conforms with slight inequalities to the spheroidal figure which would be assumed by a fluid body having the mean density of the earth and revolving with the same velocity. As the earth has therefore the form which the joint action of gravity and of the centrifugal force produced by its diurnal revolution would impress upon it; we infer that its form is the result of the joint action of those forces: and as the energy with which it would assume a spheroidal figure is not very considerable, we infer that there could have been in the beginning no rocks of great thickness and solidity to oppose and prevent a free motion of its different parts, or that it was as stated in the proposition a fluid or semifluid mass.

With regard to the cause of its fluidity two opinions have been entertained, one that the solid matter of which it is in part composed was originally dissolved in water (Sec. 14); the other that it was fused by an intense heat, with which it parted by radiation, until a crust formed upon its surface; its temperature being gradually reduced until it was fitted to become the abode of organized and living beings, and that its interior is still a mass of liquid fire. (Sec. 36.)

The first of these hypotheses is now utterly abandoned. The water of the existing oceans is inadequate to effect the solution of a thousandth part of the matter constituting the strata of the globe. Between the two parts of the second there is a very intimate connexion. If the primeval liquidity of what is now a body of earth and solid rock was produced by intense heat, we may conclude that a high temperature still prevails in its interior parts; if we have evidence of the existence of such temperature, it is best accounted for by supposing it to be the remains of what was once common to the whole mass. Those facts and arguments therefore which tend to establish the truth of one of the parts of this hypothesis, bear strongly, though indirectly upon that of the other.

44. *Of the original temperature of the earth.* 1. The whole of the vast expanse, stretching out on every side of us to a distance of which the human mind can with difficulty, if at all, conceive, is thickly scattered over with bodies which from the light that constantly emanates from them, we are warranted in believing are at this moment, intensely heated. The earth being one of this vast collection of bodies that are floating in the regions of space, the idea is very naturally suggested that it may once have resembled them in every respect, in temperature as well as in figure and other characters; that the first act of Omnipotence when the work of creation began, was, to strew the fields of ether with burning orbs. The reason why the earth should differ from most of the others now, is apparent. Its diminutive size is such as to admit of its having parted with its excess of caloric by radiation, whilst they in consequence of their greater magnitude continue to glow.

2. The figure of the earth being that which would be assumed by a liquid having the same density and revolving with the same velocity, it is inferred as we have just seen, that it was originally fluid. For producing this condition of the now solid material of the earth's crust, it is necessary to suppose the existence of an agent, or of agents, no longer found upon its surface. Werner supposed the agent to have been water; there is at least an equal probability that it was heat or fire. The excess of water required for the solution of the existing continents, over that of the present ocean, must have been annihilated. Its disappearance

can be accounted for in no other way. Heat may escape by radiation. From the figure of the earth therefore, we infer not only that it was originally fluid, but that its fluidity was produced by fusion.

3. The same condition of things is further indicated by the crystalline structure exhibited by the primitive rocks and especially by granite. The constitution of the whole mass of some of these rocks, as (granite and gneiss,) and crystals imbedded in others, (as mica slate,) prove that at some time previous to their consolidation, the particles of which they are composed enjoyed freedom of motion, and liberty to arrange themselves in obedience to the laws by which their mutual affinities are regulated and governed. At the points where granite comes into contact with gneiss, mica slate, clay slate, or another mass of granite, it is often seen to send out veins into those rocks, demonstrating that it is itself of more recent origin; that they, having been first consolidated, were rent and broken by some of the forces that are active in the crust of the globe, and the granitic material of the vein injected in a melted state into the fissure that was thus formed. (Sec. 18.) In the liquidity of the granite which constitutes a vein, is involved that of the mass from which it issues, and of which it is a branch, and in the formation of the granite of a vein by cooling from a state of igneous fusion, a similar origin of this rock wherever it is found. But as we have at present upon the earth no source of heat of sufficient power to melt the mountain ranges of granite that traverse the surface of the globe, we infer that their former fluidity depended upon their original temperature.

4. The organic remains that are found imbedded in the secondary and tertiary strata, prove that the higher latitudes at least, were once much warmer than at the present day; that a climate approaching to that of the equatorial regions, or perhaps even hotter than what now obtains in any part of the world, prevailed within the polar circles. The coal beds have evidently proceeded from the vegetation of the most ancient times. But in the shales that accompany them, we find sometimes the plants themselves imbedded, and sometimes merely the impressions they left behind them upon the clay that has since been hardened into shale, whilst it was yet in a soft and yielding state. But these plants appear to have been altogether different from those now inhabiting the countries in which the mines lie, and to have approached in their forms and mode of growth the arborescent ferns and other vegetables of tropical climates. In the Isle of Sheppy at the mouth of the Thames, the fruit or seed vessels of not less than 700 species of vegetables have been discovered, very few of which agree with any that are known to be now produced upon the earth, and the greater part resemble more nearly in their form and mode of growth those that inhabit the torrid, than such as belong to the temperate zone. The remains of animals of those races which live only in the hottest climates, (the elephant, rhi-

noceros, hippopotamus, tapir, &c.,) that are from time to time found enveloped in the soil of northern countries, also point to similar conclusions in regard to the mean temperature in very ancient times of the regions in which they occur. The animal and vegetable fossils brought by Capt. Parry from Melville Island, in latitude 75°, bear an intimate resemblance to those of England and the United States.

At the present day, the climate of every part of the earth's surface is determined principally by its latitude. The facts just stated, indicate a different condition of things at the period when the secondary and tertiary strata were deposited ; that there was then a nearer approach to uniformity of temperature in all parts of the world; such as could have been derived only from a common focus or source of heat beneath the surface ; the remains of that by which the solid rocks were once held in a state of fusion.

45. *Of the present temperature of the interior parts of the earth.*—Observations made in mines in the western part of Europe and in Mexico, indicate an increase of temperature as we descend. When this fact was first announced, the greater heat found in the deeper strata was attributed to other causes, and especially to chemical changes proceeding there, such as the conversion of the metallic sulphurets into sulphates, the animal warmth given out by the workmen, the combustion of numerous lamps and candles employed in lighting the mine, and of gunpowder used in blasting the rocks,—also to the compression of the air produced by the lengthening of the atmospheric column—rather than to a permanent elevation of temperature in the central mass of the globe. M. Cordier collected and compared the results obtained by preceding observers, and added others, the fruit of his own researches. In these last also, such precautions were taken to avoid the causes of error which were supposed to have vitiated the earlier experiments, that it is very difficult to avoid the conclusions to which they seem to lead.

The tin and copper mines of Cornwall have been wrought to a considerable depth beneath the level of the sea. They are drained through an adit or tunnel, commencing at that level, upon the coast, and carried into the heart of the mining district. Into this all the water that collects in the mine, whether flowing from the higher parts, or raised by the steam engine from greater depths, is conveyed along the channels cut for the purpose, and finally discharged at the mouth of the adit at the rate of 1680 cubic feet per minute, or 287,000 hogsheads per day. Its temperature at this point is 19 degrees above the mean temperature of the air and earth at the surface. It is calculated that the heat created by the respiration of the workmen, by the combustion of lamps and candles and other causes, would not be sufficient to raise the temperature of such a mass of water more than a single degree.

Results corresponding to these have been obtained wherever observations have been made in mines of considerable depth ; by

Cordier in the coal mines of the south, the middle, and the north of France, by De Trebra in Saxony, Humboldt in Mexico, and Daubuisson in Saxony and Britanny. Coal mines have one advantage over every other for this kind of investigation. The excavations being carried rapidly forward, there is little opportunity for the foreign sources of heat just mentioned, to operate, so that the temperature at the point where the coal is being taken, represents truly, that of the part of the earth's crust in which it lies.

In the deepest coal mine in Great Britain, at a point 1584 feet below the level of the ground, and 1500 beneath the level of the sea, the thermometer on the 15th of Nov. 1834, stood at 68° in the air close to the coal, and at 71°2. when left in a hole bored into the coal, for a week, the temperature of the day of observation being 49° and the mean temperature of the surface, 47°6.

The rate of increase is different at different places, depending as is supposed upon the greater or less conducting power of the strata and other unknown causes. One degree of Fahrenheit for 45 feet of descent may be assumed as an approximation to an average. At this rate, the temperature of boiling water (212°) will be found 6795 feet, or somewhat less than a mile and one-third beneath the surface at Chapel Hill, and a heat intense enough to fuse the rocks at a depth of between 50 and 60 miles. We have no data for forming even a probable conjecture respecting the temperature of the centre. If the interior is an homogeneous fluid, it is obvious that uniformity of temperature would be produced by the currents that would be established in it. If it is composed of metals, ranged in the order of their specific gravities, no certain inferences can be drawn from observations made in the exterior crust.

2. When the surface of the earth is occupied by tertiary deposits, a supply of good water, is often not to be had at moderate depths, and it becomes necessary to bore through the upper strata, which either yield no water at all, or such as is unfit for use, by reason of the quantity of salts of different kinds that it holds dissolved. These deposits are commonly arranged in successive layers around the sides and over the bottom of a basin, which is frequently of no great size or extent. When a stratum of pure sand intervenes between two strata of clay, the former yielding almost a free passage, whilst the latter are nearly impervious to water; if a hole 3 or 4 inches in diameter be driven by boring, from the surface, through the uppermost bed of clay, to some distance into the sand; and a casing of tin, copper, or lead introduced to prevent the ingress of water from the strata that are penetrated, an abundant supply of excellent water is often obtained. This is raised by hydrostatic pressure, exerted around the sides of the basin, to a greater or less height along the tube, sometimes to the surface, and in many cases it is seen to overflow at the surface, forming a copious and perennial spring. Having been first known

and used in the province of Artois in France, (the ancient Artesium) these have received the name of Artesian wells.

The water yielding stratum of sand has sometimes to be sought at great depths, and in the course of the operations employed for reaching it, evidence is obtained of the same general kind with that afforded by mines, that the temperature increases as we descend. Artesian wells are sometimes but more rarely obtained among the secondary strata.

3. The hot springs which rise out of the earth in many parts of the globe, but appear to be more numerous near the line of junction of the primitive rocks with the more recent strata, indicate that the internal sources of heat are not confined to the neighborhood of volcanic mountains or the mines of western Europe. Such as are particularly remarkable for the quantity, or the temperature of their waters, have attracted attention, but it is only recently that their bearing upon the science of Geology has been seen, and that they have become particular objects of interest and observation. Their peculiarities were formerly attributed to chemical changes of limited extent and influence, proceeding in the strata from which they rise. But the volume of the water given out by them in many instances, its temperature, and purity, indicate rather a temperature elevated considerably above that of the surface, extending through the whole mass of rocky strata in which they have their origin. It is evident that this heat may be derived by slow communication from an internal nucleus. If hot springs shall be regarded as furnishing satisfactory indications of the existence of an interior source of heat, a very great amount of evidence may be drawn from this quarter, since there are few countries in which they have not already been discovered, and it is probable if not certain, that a diligent search over the whole earth would lead to the detection of many that are hitherto unknown. The gas that issues along with the water of hot springs is generally nitrogen. The warm springs of Buncomb have a temperature of about 104 of Fahrenheit.

4. Some of the phenomena of earthquakes accord with the idea that the crust of the earth is a mass of rock resting upon the surface of a subjacent liquid. Such are, the vibratory motion into which it is thrown, and the heaving of the ground resembling the boiling of a fluid or the billows of a swelling sea that have been observed in a number of instances. A person standing upon a float of logs or a large piece of loose ice, will be agitated somewhat in the same way as during an earthquake. This argument is not however of any great weight. A heavy carriage driven rapidly over a pavement will shake the edifices in the neighborhood. A considerable commotion in its interior, by whatever cause produced, would perhaps be adequate to the production of all the phenomena of earthquakes, even supposing the earth to be solid throughout its whole extent.

5. Volcanoes will not as obstinately defy our attempts to as-

sign the causes of their activity, and state the modes of their action, if we suppose the interior of the earth to be an intensely heated and fluid mass. It is probable that if so constituted, a portion of the melted matter will from time to time escape in consequence of some change it undergoes.

46. The facts and arguments of the two preceding sections, directed; those of the 44th, to the proof of the more elevated temperature of the surface of the globe in the most ancient times; those of the 45th to the present condition of its interior mass, furnish a good example of the difference that generally obtains in the character of the evidence that is offered in the two great branches of geological science. In positive geology the proof is direct and simple. The thermometer indicates a constantly increasing temperature as we descend into the earth. That we may be qualified to appreciate the force and certainty of the evidence on which the conclusions of theoretical geology are founded, we must have studied the laws that regulate the organization of living plants and animals, and also of those races which are extinct and have left their remains behind them, and of the distribution of both through the different climates of the globe: we must also by long continued and often repeated examinations, have become acquainted with the appearances they present, whether at remote points or where they come into contact with each other. To the mind thus furnished and prepared for these investigations, the conclusions at which geologists have arrived in the two branches of the science, will appear to be of nearly, if not quite, equal safety and certainty. In the present instance, the two, forming essential parts of the same theory, lend each other a mutual support.

Astronomy has within the present century proposed to ascend to a still earlier epoch in the earth's history; when the solar system of which it is a part, was a hot and luminous vapour, resembling in appearance when viewed from a distance, the nebulæ that are still observed in some parts of the heavens. Under this attenuated form, the matter of our system is conjectured to have extended beyond the orbit of the planet Uranus, and to have revolved upon an axis from west to east. As it parted with its heat by radiation, it would be condensed, and every particle describing a smaller circle, that the amount of motion might remain the same, the velocity must be continually accelerated. The centrifugal force is supposed to have been so much increased, that at distant intervals, the matter of the planets separated from the principal mass, each assuming a globular form, revolving on its axis, and circulating at that distance from the centre of gravity of the system at which the separation took place, and some in the progress of their condensation, affording other or secondary planets in their turn. By means of this hypothesis, some remarkable phenomena of the solar system are easily explained.

47. PROP. II. *The primitive rocks were first formed and consolidated, and their consolidation took place before the existence of either plants or animals.*

The primitive rocks underlie the others, and the rock or stratum which rests upon another, must in general be the more recent of the two. To this conclusion we must at length arrive whatever theory of the earth we adopt. If its original liquidity was produced by heat, there must in the first instance have been formed upon the surface of the molten flood, a substratum or floor for the deposits of succeeding times to rest upon. That crust of consolidated matter is a crystalline primitive rock, and though parts of it were afterwards broken and constituted the material for the mechanical aggregates of a later period, yet is it true that the most ancient transition stratum is of more recent origin than that on which it reposes. By some geologists, gneiss and mica slate are regaded as the most ancient of the rocks, as constituting the original crust that was first of all spread over the surface of the liquid mass. *Beneath* these a bed of granite was gradually produced by the radiation of heat into the surrounding space, and *above* them in some instances, the transition and secondary strata. Where granite appears as it frequently does, at the surface, and at great elevations, upon the summits of mountains, it is not necessary to suppose that it assumed its form and was consolidated in its present position. It may have existed as a rock beneath the general surface of the globe, and been raised, either gradually or during some great convulsion, to the position in which we find it.

As no organic remains of any kind are imbedded in the primitive rocks, we infer that they never contained any, and that they were consolidated before either plants or animals existed, it being improbable that if their consolidation was either coeval with or posterior to the existence of organized beings, they would embrace no evidences of this fact. It is possible indeed that the favorite theory of some geologists is true, that organic remains once existed in the materials from which these rocks were formed, and were destroyed by the action of fire or water during the fusion or solution they must have undergone before assuming the forms and characters they now exhibit, but no appearances have been observed which lend any degree of probability to this opinion, and there is a considerable probability against it. Commencing with the higher strata, the remains of every kind are numerous, as we descend, their number gradually, though not uniformly, diminishes, till in the transition class, we find only the remains of zoophytes—a race occupying the lowest place in the scale of living creatures. It was to be expected that this descending series would have a limit, where the traces of life whether animal or vegetable should cease altogether. Such a limit we find in the primitive rocks, and though it is possible that the strata in which we find no traces whatever of life, once teemed with living beings which have been destroyed, it is much more probable that they assumed their present form before there was either a plant or an animal to be imbedded in them.

48. Prop. III. *The transition and secondary rocks which are now found with their strata highly inclined, were deposited and consolidated in horizontal beds.*

They bear an intimate resemblance to those accumulations of fine clay, sand, and gravel, that are now found in the bottoms of lakes and the estuaries of rivers. There are the same alternations of coarse and fine materials, indefinitely repeated, and without any approach to regularity. They are evidently made up of what was once a loose mass, destitute of cohesion, and which by the infiltration of siliceous, calcareous, or ferruginous matter and by other causes has been converted into rocks. Such a mass if placed upon a plane that is considerably inclined, will not arrange itself in beds or layers parallel to the surface of the plane, but will roll, sink, or slide down to its lowest point. In so doing it will only obey the most general of all the laws that regulate the material world, the law of gravity.

The case is particularly clear when very thin layers of shells or pebbles are interposed between two adjacent strata. It would in many instances, have been quite impossible for them to gain the positions in which they are found, in any other way, than by being strewed uniformly over an horizontal surface, and then covered with a stratum of a different kind. These arguments will not apply to all the transition and secondary strata : they are applicable to the most of them ; and the rest will be found so alternating with, or imbedded in those to which it does apply, that whatever decision we pass upon the one class, we shall find ourselves under the necessity of extending to the other.

49. Prop. IV. *The secondary, transition, and in many cases the primitive strata, have been shifted from their original positions into those which they now occupy, by forces which have operated since their consolidation.*

This proposition follows as a necessary corollary from the two preceding, and is introduced less with a view to a formal proof of its truth, than to an enquiry respecting the nature and mode of action of the forces by which the changes referred to in it have been produced. If these strata were deposited and consolidated in horizontal beds, and are now found sometimes almost in a vertical position, it is plain that a force of some kind has been applied to them by which their situation has been changed. It may have been the force of gravity, the substance which supported one of their edges having been removed, and that edge left to subside by its own weight ; or the other edge may have been lifted up by a force acting from beneath.

A mill-pond which has been covered with a thick sheet of ice during a cold night, and from which a part of the water has been drained off, the next day, furnishes a good representation of the appearance of the *secondary* strata especially, over the surface of the earth. In places where the pond is deep and free from drift-wood, the ice will subside regularly and uniformly along with the water, but if there is an island any where in the pond; or a large rock, or any thing of the kind, presents an obstacle to the regular subsidence of the ice, it will be seen broken and reposing upon the side of the rock or island, at a great variety of angles of inclination.

This is the actual appearance of the secondary and transition strata. At a distance from any primitive mountain, as in the south-eastern part of England, they are parallel to each other and nearly parallel to the horizon. In the neighborhood and on the sides of the Alps on the other hand, strata of the same kind of rock occur in the utmost confusion and disorder, deranged and contorted in every direction and declining towards every quarter of the compass at every angle.

The party which went out in the year 1819–20, under the command of Major Long, to explore the country west of the Mississippi, found a vast desert with a substratum of sandstone stretching eastward from the Rocky Mountains through a distance of more than 400 miles. The strata which constitute this formation of sandstone are sometimes nearly horizontal and sometimes considerably inclined. Near the mountains they are generally horizontal until we come to the very foot, where they are suddenly elevated in vast tables, into a position approaching the perpendicular. These appearances may be accounted for, either on the supposition that the Rocky Mountains retain their primitive position, and that the whole body of the sandstone has sunk down from the higher level which it once occupied, and left the upright tables resting upon the sides of the mountains—or we may suppose that the sandstone now occupies the position in which it was originally consolidated, and that the Rocky Mountains have been forced up through it from below, deranging and displacing in their passage such of the superincumbent strata as were near enough to be effected by them. One or the other of these conclusions appears to be unavoidable.

There is evidence that in some localities the elevation, in some the depression, and in others successive elevations and depressions of limited portions of the earth's crust, have brought the rocks into the positions they now occupy. Thus on the southern coast of England, a stratum of marine origin is covered by a bed of black mould containing the petrified trunks of large trees and their stumps still standing erect in their native soil. Over these, fresh water, and higher still, other marine formations are accumulated to a thickness of more than 2000 feet. It is evident that the lower marine stratum must have been raised out of the sea, and a soil formed upon its surface, in which a forest took root and grew, and that the whole was afterwards for many ages the bottom of a deep ocean. It is now a second time dry land. Similar oscillations and changes of level are known to have occurred elsewhere on the surface of the globe, and it may be conjectured that they have not been uncommon. But of the two movements, upward and downward, if we may judge from characters of the strata to which we have access, the former have been more frequent than the latter. Organic remains of marine origin are found imbedded in great abundance along the sides or on the summits of mountains, but this is not quite decisive. We do not know what submerged continents may now be covered by the waters of the ocean. The conclusion may however be regarded as warranted by the facts, which living geologists have generally regarded themselves as under the necessity of adopting—that the mountains which are called primitive, though existing probably in the form of rocks within the bowels of the earth, have been forced up through the transition and secondary strata, producing that confusion and disorder which are so strikingly exhibited in the neighborhood of the great mountain chains.

50. Prop. V. *It is probable that the causes which are now active in the production of the phenomena of earthquakes and volcanoes, have effected important changes in the features of the globe, in particular that they raised the primitive mountains out of the bed of the sea. They also brought into existence under their present form, a class of rocks (the trap rocks) that were the subject of fierce contention between the rival schools of Hutton and Werner.*

We have now come to one of the most difficult problems in the science of geology; that of accounting for the changes that have just been stated and described. The unstratified rocks, and especially granite, have been heaved out of the bowels of the earth, carrying with them, and before them, strata that had been accumulated at the bottom of the ocean, and have thus formed the existing continents. How? What is the nature of the force by which effects so vast and magnificent have been produced? There will be given by way of introduction to the discussion of this question, a brief account of the controversy that was maintained with the utmost degree of vehemence and bitterness, about half a century ago, respecting the origin of the Trap Rocks.

At a distance of about fifty miles from Freyburg where Werner taught mineralogy, the Erzgeberg mountains, rich in the metal ores, separate Saxony from Bohemia; the chain being about one hundred and twenty miles in length. Some of the highest peaks of the chain, or of the spurs that make out from it, have a cap of basalt upon their summits. The basalt is in the form of huge blocks, two or three hundred feet in thickness. It occurs on fourteen different mountains, scattered over an area of 600 square miles, but the surface of all the basalt taken together does not much exceed a single square mile. The mountains themselves, are primitive, being constituted of granite, gneiss, and mica and clay slate. The basalt sometimes reposes directly on these rocks, and is sometimes separated from them by a thin layer of sandstone. Galleries have been driven under the basalt for the purpose of procuring ore from the subjacent formations, affording the means of ascertaining beyond all doubt, that it cannot have been thrown up from below. Werner finding it lying in some cases upon a rock evidently secondary, and seeing upon the spot no evidence of its igneous origin, classed it with his secondary rocks that have been deposited from water. The correctness of this classification was questioned by other geologists, and the disciples of Werner holding themselves bound to maintain the positions of their master, there arose a long and angry dispute respecting the origin of basalt, and in general of the floetz or secondary trap rocks.

Secondary trap formations are seldom extensive. The rocks of this class do not constitute great mountain chains. They generally occupy an unconformable and overlying position on the top of other strata. Sometimes they are irregular shapeless masses, but they occur also in tables and of a globular form. A large block of basalt is often divided by fissures into prisms, the number of the sides of which is variable, from three to nine. Four or five sides are the most common. The sides of a trap formation frequently present high perpendicular precipices, or a succession of these, of less elevation, creating in the latter case natural terraces, whence the name of *Trap Rocks* from the Swedish, trappa, signifying a stair. The neighborhood of Edinburgh, the Western Islands of Scotland, the North of Ireland, and the Northern States furnish examples.

The igneous origin of the trap rocks has been inferred from a variety of facts and observations, some of which are here stated.

1. Basalt and some varieties of *compact* lava very much resemble each other. They have the same texture, color, and appearance of having been subjected to the action of fire. That variety of basalt on the other hand, which bears the name of Amygdaloid, imitates very exactly *porous* lava. After having been exposed to an intense heat, basalt and lava if suddenly cooled, assume the characters of glass, if slowly cooled, of stone. The general range of their characters, both physical and chemical, is much the same. Basalt passes by insensible gradations into the other trap rocks, so that whatever be the opinion that is entertained respecting the one, it must be held in regard to the others.

2. The position of the trap rocks, with respect to other rocks and strata, is generally that which a mass of matter would assume if poured in a fluid or semi-fluid state from a volcano. The superincumbent and overlying position is peculiarly appropriate to rocks that have been formed in this way.

3. Basaltic rocks are most frequently met with in those countries which exhibit other proofs of having been the seats of volcanic action. Daubisson when he had seen only the basalts of

Saxony, wrote a book in defence of the doctrines of Werner, but after visiting the mountains of Auvergne, he was satisfied that the basaltic formations of that country are the products of volcanoes, and disposed to generalize the proposition, and refer all rocks of the same kind to the same origin.

4. When beds of limestone, or coal, are traversed by dykes of basalt, or lie adjacent to a body of that substance, they are often much altered at, and near, the point of contact ; the limestone having been made to assume a crystalline structure, and the coal deprived of its bitumen, and charred, and we know of no way in which contiguous strata could produce this effect, except by the intense heat of that which has changed the condition of the other.

The reasonings of the Wernerians were generally presented under the form of objections to the doctrines of their opponents, rather than as positive arguments in favor of their own opinions. Thus in the case of the basalts of Saxony: mines have been run quite under them, and it has been thus ascertained that they cannot have been thrown out of the bowels of the mountains on which they stand. The inference was drawn that they cannot have been produced by the action of fire : but whether we call in one or the other element, fire or water, to aid us in the formation of these rocks, their position is equally embarrassing.

The great extent of some formations of basalt, was proposed as an objection to the opinion that this rock is of igneous origin. But when it is considered that the bed of lava which flowed from Mount Heckla in 1784, is ninety-four miles in length, fifteen in breadth, and in some places from eighty to an hundred feet in thickness, the magnitude of the largest trap formation cannot be regarded as presenting any very considerable difficulty. The last century furnished another example of the energy with which volcanic action may be exerted without convulsing the earth to any great extent. On the night between the 28th and 29th of September, 1759, a tract of country four miles square, in the intendancy of Valladolid in Mexico, which had formerly been cultivated ground, was thrown up to an elevation, at the highest point, of about 1500 feet, (the height of the Pilot Mountain above the surrounding country very nearly,) and converted into a volcano, and yet this event was unknown to men of science until Humboldt visited Mexico at the commencement of the present century.

It was further urged by the Wernerians that basalt sometimes traverses or touches, strata of coal and limestone, without producing any change in those substances at the point of contact, and that it also embraces animal and vegetable remains. These are considerations of real weight, but the inference drawn from them was rejected on the ground that the examples cited were few in number, and that the facts had in these cases been either misapprehended or misinterpreted. The belief is universal amongst geologists of the present day, that basalt is of igneous origin, and in arriving at this conclusion, they have been led to include with it, granite and the other unstratified rocks.

51. But how have these last been produced? In what particular way have they after their formation been heaved out of their beds, and placed at great elevations above the level of the sea? Is there any analogy either intimate or remote, between the causes and circumstances that have formed beds of lava upon the surface, and those which created and raised into its present position, the block of granite on which the University stands? On these points the opinions of geologists are widely discordant.

1. It has been supposed by some, that there is a close resemblance in the formation of beds of lava and masses of granite, the causes to which they owe their origin, and the mode of their action, being nearly the same for both: That they are the result of chemical changes which are constantly proceeding within the crust of the earth, and which either operate unseen and in silence, until a force is accumulated that is superior to the resistance to be overcome; or acquire from time to time new activity, because fresh masses of matter are brought into contact with each other. In either case, there is a sudden and irresistible action, by which long ranges of mountains are thrown up in the course of a few weeks, or months, when the disturbing force appears to be exhausted and sleeps for ages. The history of the earth, according to this hypothesis, is made up of brief paroxysms of violence and convulsion, and long intervals of repose.

2. Other geologists have represented that the amount of geological change has been in all ages pretty nearly the same; that the existing continents have been raised from the deep by a succession of movements, each so small as to have escaped notice at the time of its occurrence, and which are still continued. Thus some parts of the coast of Sweden are said to be rising at the present day, but so slowly, that the fact is ascertained only by a comparison of observations made at intervals of from fifty to one hundred years. That there has been no change of the relative level of land and water around the shores of the Mediterranean, during many centuries, is proved by the fact that the stairs for descending to the water's edge, and the landing-places there, which were constructed by the ancient Greeks and Romans, are in use at the present day.

3. But neither the paroxysmal nor the secular hypothesis assigns with precision and certainty the mode by which the effects supposed by it are accomplished. Granting that the causes of chemical change are active in the interior of the earth; it is not apparent in what way they can operate to produce the protrusion of the rocks and the elevation of the strata. We cannot see why they should even have any tendency to produce such effects. And even if they are supposed only to modify the level of the existing continents, by causing the depression of one point,

whilst they elevate another, the modus operandi by which they accomplish this is equally obscure.

4. Abandoning the idea that the dislocated and tilted condition of the strata is the result of chemical agencies, some philosophers have turned their attention to the gradual refrigeration of the globe, as the great cause of geological changes ; but still with discordant views respecting the manner in which it would operate. A ball consisting of an exterior solid crust, and an interior liquid mass, is floating in a medium whose temperature is less elevated than its own : What law will the cooling observe as it proceeds ? Will it be most rapid, and the contraction most considerable, in the crust, or in the fluid it contains ?

5. M. Elie de Beaumont supposes, that it will be greatest in the latter, and that the crust becoming too large for the body it is required to cover, will collapse, and accommodate itself to the diminished magnitude of the internal nucleus, rising into ridges along certain lines that are not very remote from each other ; and that it is in this way that the strata have been shifted from their original positions, and mountain ranges formed. M. Cordier, on the other hand, represents that the cooling and contraction will be the greatest in the crust. Fissures must therefore be created in some places, to which it may be expected that the superabundant matter will be directed by the pressure of that part of the crust in which the cohesive force is not yet overcome. This must produce a bulging out of the surface along the line of the fissures; a ridge of granite, with the transition and secondary strata adhering to it, and reposing upon it in an inclined position, on each side. This hypothesis agrees better with the facts therefore than the other.

Whether we shall ever arrive at accurate knowledge, and conclusions in which we may repose undoubting confidence, respecting the primary causes of geological phenomena, is perhaps doubtful. The minds of the philosophers who are engaged in the cultivation of this science, are now directed with intense interest to this particular subject, and it may be hoped that correct results will be obtained. But even if they should not, the value of the knowledge we already possess, will not be much the less on that account. Until within a very few years, it was the commonly received and accredited doctrine, that light consists of minute particles, thrown off with immense velocity, from the luminous body. At present, the opinion that the phenomena of light are the effect of undulations produced in an elastic medium dispersed through the universe, threatens to supplant the other. But whether we embrace one or the other hypothesis, all the great principles and doctrines of the science of optics will remain unaffected, and with no diminution of their truth and certainty. And so will it be with regard to the cardinal facts and doctrines of geology, whatever the uncertainty under which we labor in regard to the primary causes of geological changes.

52. Prop. VI. *After the strata constituting the present crust of the globe had been deposited, and before the consolidation of the most recent secondary rocks, vast currents swept over its surface, and in some instances scooped out deep vallies, and in others transported rocks to a distance from their original beds.*

Of the propelling power which put these currents in motion nothing is known with certainty; whether for example they were rivers, conveying the waters drained from a continent to the ocean, or like the Gulf Stream, established in the ocean itself. The evidences of their existence are still extant in the marks of their ravages that remain. Nor is it meant to be asserted that all vallies have been formed by the action of currents.

The attention of geologists was first called to the circumstances under which boulder stones are found dispersed over the northern parts of Switzerland, by Saussure. The Alps range along the southeastern border of that country. Mont Blanc, the highest peak, attaining an elevation of more than fifteen thousand feet, is a block of granite, in which talc and chlorite are substituted for mica. On the northwest, Switzerland is partly bounded, and partly traversed, by Mount Jura, presenting strata of secondary limestone. The two ranges are separated by deep vallies, in which flow, the Rhone, expanding in one part of its course so as to form the lake of Geneva, and the Aar. On the top and along the sides of Jura are found huge blocks, which have apparently been torn from the opposite ridges of the Alps, and in some way or other transported across the valley. They have no connexion with, or resemblance to, the strata on which they lie, and are identical in composition, and structure, with the rocky masses that abound in the Alps. Respecting the manner in which their removal has been effected different opinions have been entertained :—that they had become enveloped in a body of ice, when the compound mass being lighter than an equal bulk of water, floated away, and eventually subsided into the situations in which the granitic blocks are now lying; that they were blown into the air by the force which elevated the Alps and descended upon Jura; that they were torn from the Alps, and carried down the sides of those mountains, with a velocity that caused them to roll up the side of Jura; that there was once a continuous inclined plane reaching from the upper regions of the Alps, to the summit of Jura, along which they were rolled into their present beds, and that the intervening vallies were scooped out afterward by a current; that the elevation of Jura was subsequent to that of the Alps, and that whilst it was yet on a level with the base of those mountains, the boulders were rolled down upon it, and afterwards elevated along with it. The alluvial shores of the Baltic present examples of erratic blocks, brought apparently from the mountains of Sweden and Norway. They occur also in the valley of the Ohio.

If these should be thought ambiguous examples of the action of currents, there are others where the fragments can be traced back, along the track of the current, to the rock from which they were torn. Instances of this kind occur in England, which prove that in that country, the movement of the waters was from the northwest towards the southeast. In many parts of the northern States, vast heaps of sand, gravel, and rounded pebbles, are piled up in the heart of primitive districts which must have been brought thither by currents. They are sometimes many feet in height, and cover extensive tracts. When cut through by torrents, they exhibit layers of rounded stones and sand, of different degrees of fineness, resting on each other, and different from the subjacent rock on which they repose. If we except the low country ; parts of which I have sometimes suspected to have an intimate connexion so far as relates to the time and mode of their formation with these deposits; we have no similar appearances in North Carolina.

Many valleys have been formed by the action of currents. "When a valley takes its beginning, and continues its whole extent, within the area of strata that are horizontal, or nearly so, "and which bear no marks of having been moved from their original place, by elevation, depression, or disturbance of any "kind ; and when it is also inclosed by hills that afford an exact correspondence of opposite parts ; its origin must be referred to the removal of the subtances that once filled it. And as "it is quite impossible that this removal could have been produced in any conceivable duration of years, by the rivers "that now flow through them, we must attribute it to some cause "more powerful than any at present in action, and the only admissible explanation that suggests itself is, that they were excavated by the force of water in motion."—*Buckland, Reliquiæ Diluvianæ.*

Hutton and Playfair maintained that all vallies have been formed by the long continued erosion of the streams which actually run through them ; but there are innumerable instances where streams do not exist, or where they are wholly inadequate to the production of the condition of things that is observed. From the effects of the water that falls under the form of snow, or rain, upon the soil of our fields, in forming gullies, and sweeping away the finer particles and depositing them in the beds of the rivers ; the idea that the vallies in which those rivers flow have been scooped out in a long succession of ages, strikes the mind in the first instance, as in a high degree probable. But when we attend to the actual progress of the water in wearing away their beds, and observe also the sharp angles of the rocks to a great height on each side, and the absence of those marks of attrition which must have been found, had the valley been created in this way, we see the necessity of a more efficient cause. If we trace the streams to the ocean also, we find the deposits at their mouths by no means commensurate to the quantity of soil which would be necessary to fill up the vallies in the interior. Other objections might be proposed. Cases occur where there is such a combination of longitudinal and transverse vallies, as proves incontestibly, that the bed of the river was first formed, and the water afterwards flowed in it, in obedience to the law of gravity, but without exerting any considerable agency in producing its excavation. The Shenandoah and Potomac rivers in Virginia, will furnish an illustration, though they they may not afford an example. Mr. Jefferson supposes that the Blue Ridge was first thrown up, that the two rivers afterwards began to flow, and to form a lake behind the mountain, which continued to rise, until it reached the crust of the ridge, when it broke over, and gradually tore away the strata down to the present level of the bed of the stream. This may be a correct account of what took place at the point where the Potomac passes the ridge, but cases occur on the surface of the globe, where the appearances are the same, so far as relates to the rupture of the mountain barrier, but it is found on examination, that the crest of the mountain is higher than the head of the river, or than some other point on the edge of the basin, within which the waters are supposed to have been confined, before they broke through : and if the elevated land which separates the head waters of the Shenandoah from the waters of James River, shall be found to be lower than what was the original gap in the Blue Ridge at Harper's Ferry, or if any other point in the ridge, shall turn out to be lower than the same gap, it is evident that the proposed explanation of the appearances will be inadmissible. We must then resort to some of those primeval currents that have changed the face of other countries.

The existing vallies may be referred to three principal causes.

1. The irregular elevation and subsidence of the rocky strata of the globe, which have produced the greater inequalities of surface.

2. Currents established in the ocean whilst large parts at least of the present continents were covered with water. By these the secondary strata have been torn away in places, and over large areas, to a depth of some hundreds of feet, and the materials carried off, creating what are called *denudations ;* the inferior beds having been uncovered and brought up to the surface. Of this, the district between London and Brighton on the southern coast of England furnishes a remarkable example. When the effect is such as to create a depression below the general surface of the country there is formed a *valley of denudation.*

3. *Rivers.* These are constantly, though sometimes very slowly acting upon their beds, and changing the form and aspect of the vallies through which they flow. It is evident that those depressions in their channels in which lakes are formed, must gradually disappear, being partly filled by the alluvion brought in at their upper, and partly drained by the wearing away of the

barrier at their lower extremity. A great number of lakes, is therefore an indication that the region in which they lie, has but recently emerged from the ocean, and it is remarkable that the country around the Baltic, which is supposed to be rising gradually at this time, abounds in them, especially that part of Russia which borders on the Gulf of Bothnia, and bears the name of Finland. The southern States being without lakes, it may be inferred that the era of their emergence is exceedingly remote, at least when compared with that of Maine, and the other New England States, the tertiary deposits of the seaboard, of course excepted.

53. Prop. VII. *Since the consolidation of the crystalline or primitive rocks, the earth has undergone a great number of catastrophes and revolutions, by which its face has been changed. It is probable that in most cases, if not in all, the causes of these mutations in its condition and aspect, were local, and their effects confined to an area of no very great extent.*

The transition and secondary strata are made up chiefly of the rounded fragments and ruins of more ancient formations, (Sections 19 and 21.) The conglomerates, sandstones, clay-slates, limestones, and beds of clay and sand of which they are constituted, do not in themselves possess any high degree of interest. It is to the organic remains they hold imbedded that the attention of geologists has been principally directed, especially during the last 30 or 40 years, with a view of ascertaining the different varieties of animal and vegetable form and structure that have existed upon the earth, and the order of their succession, and thus arriving at some sound and accurate conclusions respecting the condition of the globe itself through a long series of ages, and the changes to which it has been subjected. The history of the secondary and tertiary strata is therefore, to a great extent, the history of organic life during the periods of their formation.

If the earth was originally a melted mass, it is evident that there must have been a time subsequent to the consolidation of the primitive rocks, when its temperature was such that water could not exist in a liquid state upon its surface, but the existing oceans hung as an atmosphere of vapor around the hot and dry skeleton of the globe. To this period must have succeeded another, when the great mass of the vapor had been condensed into water—but water not many degrees below the boiling point, and in which few animals and vegetables, if any, could live. In this condition of things, the vapory and gaseous mass surrounding the earth, would bear a considerable resemblance to the now existing atmosphere. It would be composed principally, as at present, of the incondensible gases, oxygen and nitrogen, but would be highly charged with watery vapour, and probably also with carbonic acid. All the phenomena of meteorology, evaporation, condensation, the wearing away of the solid rocks by torrents as the rain that fell rushed down to the ocean, and the formation of that mixture of fine particles of silica and alumina to which we give the name of clay, of pure unmixed sand, of gravel and shingle—all these changes would proceed with much greater rapidity than at the present day. There would be produced therefore, vast accumulations of the materials of the fragmented rocks, containing no organic remains, which by the infiltration of water containing silica dissolved in it, would be converted into solid masses of breccia, conglomerate, and clay-slate. The water of most springs is slightly impregnated with silica, but the hot springs of Iceland and the Azores, prove that the solubility of this earth is very greatly increased when the temperature of the water is raised to the boiling point or above it. It is to this remote era therefore, that we must refer the large body of rocks ; flinty and clay-slates, hornstone, conglomorate, &c. that stretches across the midland counties of North Carolina; a branch of which follows the course and forms the bed of Morgan's creek between Barbee's and Meritt's mills, and communicates with the main body at a point four or five miles northwest of the latter. It is supposed to contain no organic remains, and to have been formed anterior to the existence of organized beings, whether animal or vegetable.

South-east of this and altogether different from it, in constitution, structure, color, and the kind of soil produced by its decomposition is a body of sandstone, extending nearly across the state, which contains *coal* in Chatham, and as this substance is supposed to have had a vegetable origin, it is inferred that during the period when this sandstone was in the act of being formed, there must have been dry land at no great distance from the beds of coal, and that the existence of *vegetable* organized beings upon the earth had commenced. This sandstone is not known to contain any remains of animals, and furnishes therefore no evidence of their existence at the time of its formation.

54. With the exception of a few beds and masses of shell limestone, in the low conntry, of limited extent, and mostly covered by the sand, all the formations in North Carolina of later date than the sandstone are of very recent origin. In tracing the succession of events and of animal and vegetable forms, we are compelled therefore, to direct our attention to some other portion of the earth's surface for proofs and illustrations that are not found in the region in which we live. In an investigation of this kind, it is of but little importance from what quarter of the world these are drawn. For reasons already given ; because in the English strata there is a long succession of secondary formations, within an area of moderate extent; (Sec. 29.) and these have been studied and described with as much accuracy as those of any country ; it is to the south-eastern part of the island of Great Britain that our attention will be first and princially directed.

It appears that nearly all of the transition and secondary strata of England contain organic remains imbeded in them, and that these remains are different in the different strata. In the transition rocks are found various kinds of coral, madrepore, crinoidæ, trilobites, and other similar organic substances, very many of which are altogether different from such as are known to exist in the ocean at the present day. In many cases, not only has the species or genus, but the type or general structure and form disappeared, so that amongst the living races there is none that bears more than a distant resemblance to such as filled in countless multitudes the waters of that ancient earth. The old red sandstone and metalliferous limestone which rest upon the transition rocks, also contain these remains, and in greater abundance, but they are of a different kind, bearing however, a greater resemblance to such as are found in the transition strata than to the tribes now inhabiting the sea. The coal measures abound in fossil remains and impressions of plants, but shells are rare, and in many cases altogether wanting. The Magnesian limestone which comes next has many shells, petrified fishes, and the remains of an amphibious animal of the genus Monitor are found in it. In the new red sandstone organic remains are so very rare, that the existence of any, of whatever kind, in it was at one time denied by geologists. In the Lias first make their appearance the Ichthyosauri and Plesiosauri, large reptiles bearing some resemblance to the alligator, but furnished with paddles instead of legs and feet, as instruments of motion. Extending upward through the strata to the chalk, they have with the turtles, crocodiles, and other lizards that are associated with them, procured for this, the name of the saurian period in the history of the earth, or the age of reptiles. The Oolite abounds in organic remains consisting of corals and other shells, the reptiles of the Lias, and several different kinds of Pterodactyle; a creature in which were united the characters of a reptile, a bird, and a mammal, with wings like a bat, and supposed like him to have been abroad in search of food in the dusk of the evening or at night. Here also for the first time do we find the remains of a quadruped inhabiting the land. They are the bones of a species of Opossum.

In the strata still above, other remains of other genera occur, but traces of land animals are either few in number or altogether wanting. Chalk which was long regarded as a precipitate from water highly charged with carbonate of lime, proves under the microscope, to be an aggregation of shells too minute to be distinguishable by the naked eye. It is not till we come to the most recent strata and a bed of clay, sand, and gravel, covering all the other formations, that we find evidence that the earth has at a former, distant era, been thickly peopled by quadrupeds resembling those which now occupy its surface, though differing from them in some respects. It is in this upper bed that the fossil bones of Elephants, Hippopotami, and Rhinoceri occur.

From these facts it may be inferred, that these different strata were formed in succession, and that each in its turn has been uppermost. Whether we suppose the animals to have lived and died on the spot where their remains are found, or that those remains were brought in from abroad, and deposited in the places where they now lie, the inference must be the same. Two strata are in contact with each other; they are composed of different materials; one is a limestone, the other made up of particles of sand; they envelope different organic remains; they were both deposited from water. Can any thing be clearer than that the lower stratum was deposited first, a succession of ages being perhaps occupied in its formation; that at the end of that time a great revolution occurred, by which the condition either of the whole surface of the globe, or of a particular part of it, was changed, and by which many of the animals then existing on it were destroyed, since no traces of them are found in the rocks formed since that epoch.

A new order of things now arose, new races of living creatures came into being, and through the influence of causes which are unknown to us, a stratum of a different character was deposited. A second revolution supervened, swept off those new races and many of the remaining old ones and introduced a new era. Thus through many rolling ages has the earth been changed. The last great catastrophe it experienced was the deluge recorded by Moses in the scriptures.

But these statements and remarks relate to the south-eastern part of the island of Great Britain. A question arises respecting the amount of agreement and correspondence that has been already observed, or which we may hereafter expect to discover, between the secondary strata of England and those of other countries. Shall we find elsewhere the same number of formations succeeding each other in the same order? If the views now generally entertained by geologists respecting the original condition of the globe, and the present temperature of its interior parts, shall be deemed worthy of adoption, it will follow that the state of its exterior surface, and its relations to animal and vegetable life whilst the strata in question were in the act of being formed, must have depended in a considerable degree upon its temperature simply, and as this must have been nearly the same in every part, a general correspondence, and especially an agreement in regard to the remains they hold imbedded, may be expected, between the strata of parts of the globe remote from each other, and the formations of any one country, may be regarded as furnishing a general type of those of any other country. The resemblance is found however, in fact, to be partial and imperfect. The composition and structure of a stratum remaining unchanged, the remains imbedded in its remote parts are not exactly the same. More frequently, the organic remains being constant, the stratum or including rock will vary. A formation occupying a large space in one part of the globe, will be wanting, or its place supplied by a totally different, or as it is commonly called, equivalent formation in another. Of the whole crust of the earth, it would appear in the present state of our own knowledge, that no portion has experienced so many vicissitudes, been the theatre of so may revolutions, and presents as their effect so long a series of formations, as that which in England, France, and Germany, has been the most accurately examined. Still, the following conclusions, drawn from the appearances presented by the strata of England respecting the condition of that island whilst the changes of which its present form and aspect were the result, were proceeding, hold good to some extent for the whole surface of the earth.

1. It is probable that after the consolidation of the primitive rocks, the water bore a much larger relative proportion than it now does to the land. The remains that are found in the transition strata belong without any exception to such animals as inhabit the sea.

2. At the end of this period another succeeded, during which its surface was occupied by extensive marshes, the waters having retired from those situations which had before remained constantly covered. In this state of things it was that the coal beds were deposited. The proof of such a condition of the earth is found in the nature of the vegetable remains which are imbedded in the coal strata. They appear to have belonged to plants resembling the arborescent ferns and reeds of tropical climates, and to have been fitted therefore to flourish on marshy ground and in a meagre soil. A person who has seen the Palmetto, or Cabbage-tree, growing along the southern shores of North Carolina, will have a tolerably correct idea of what their appearance may have been. It was at this remote era therefore, that the magazine was prepared, and the whole stock of materials laid in, which now keeps the manufactures of England in activity.

3. After the formation of the coal strata, the waters again overflowed that country; and at no great distance of time, a period succeeded, during which it seems to have been almost throughout, a waste desert, without a plant or an animal existing upon its surface. Now it was that the new red sandstone, with its beds of fossil salt and gypsum, was deposited.

4. Shell fish were afterwards formed in greater numbers, and some oviparous, amphibious quadrupeds, such as tortoises, lizards, and crocodiles, were created, and as the earth was now fitted to be the habitation of such creatures, it must have been as now, terraqueous ; but as some have supposed, with the land barely rising above the level of the sea.

5. Subsequently, the mountains were thrown up and the existing continents emerged from the deep ; and the dry land having become extensive with respect to the sea, was peopled with birds and quadrupeds fitted to inhabit it.

6. Last of all, as we are informed by Moses, and as the observations of geologists warrant us in believing, MAN, the noblest of God's works, was created ; to adore, love, and serve his

Maker, to perform acts of kindness to his fellows, to speculate on the magnificent mechanism of the universe, trace the evidences of the revolutions and catastrophes which the globe on which he dwells has undergone in former ages; be filled with wonder and astonishment in meditating on the magnitude of those gigantic powers which were able thus to change the face of nature, but without ever being able to ascertain fully their nature, or determine what were the causes that quickened them into action.

55. A question will here arise in the minds of some persons, which in view of what has been handed down from our fathers, and is commonly received as revealed truth amongst us, it becomes me to be prepared to answer, and as I may without travelling out of my proper province, or abandoning those objects to which these pages are particularly devoted, invite attention to the subject, it will be taken up at once whilst it is yet fresh in the mind.

How, it will be inquired, does all this agree with the Mosaic account of the creation contained in the Bible? I might content myself with replying, "As well as the doctrines of modern Astronomy agree with what is contained in the same account." We read :—

Genesis, i. 6. And God said let there be a firmament in the midst of the waters, and let it divide the waters from the waters.

7. And God made the firmament, and divided the waters which were under the firmament, from the waters which were above the firmament, and it was so. And God called the firmament Heaven.

14. And God said let there be lights in the firmament of the heaven, to divide the day from the night, and let them be for signs, and for seasons, and for days, and for years.

15. And let them be for lights in the firmament of the heaven to give light upon the earth, and it was so.

16. And God made two great lights, the greater light to rule the day, and the lesser light to rule the night; he made the stars also.

17. And God set them in the firmament of the heaven to give light upon the earth.

18. And to rule over the day and over the night, and to divide the light from the darkness: and God saw that it was good.

The language of the last five verses, (from the 14th to the 18th inclusive) taken in its literal acceptation, would seem to inform us, that the particular and specific object for which the sun moon and stars were created was, to give light to the inhabitants of the earth. But at the present day, mankind make an allowance for the circumstances under which these words were written, and believe that the sun and stars were created for some higher object than the mere furnishing of light, and the stars a very feeble light, to the small planet on which we live, though it is also evident that giving light to the inhabitants of the earth is one of the offices they are appointed to fulfil. Nor do they regard themselves as becoming worse Christians as they become better astronomers. It is said also that the heavenly bodies were placed in that firmament, which in the 7th verse is represented as having waters under it, and waters above it, and to be therefore within the limits of the earth's atmosphere.

There is nothing in the discoveries and speculations of sound and accurate geologists, that will be found to militate against the Christian faith, when the objects of the revelations of God are well understood. It appears never to have been the object of the Deity to communicate to his creatures physical truth ; to teach them astronomy, or chemistry, or geology. He leaves them to make advances in the sciences by means of the faculties he has given them, and only instructs them in their duties to himself, and to each other, arising from their relations to Him as their Maker, and to each other, as fellow creatures. We may perhaps say with truth that this is the only object worthy of the interposition of the Deity ; that it would be beneath the Divine majesty to teach those elements of the sciences, which we shall discover in due time by the exertion of our own intellectual powers.

It being then the object of the Deity to communicate moral truth, the sacred penman does not enter into any minute philosophical details. In giving an account of what took place on the earth before the creation of man, he does not write a system of geology, and tell in what succession, and at what intervals, the strata of Palestine, England, or America, assumed their present form and were consolidated. The introduction of such matter into a book intended in the first instance for the simple and unpolished Hebrews, and afterwards, for the instruction of the poor and ignorant of every country and every age, would evidently have been inexpedient, and a proof that the writer was not under the guidance of an influence proceeding from above. In speaking of man, God must use the language of men, or he will not be understood. As in giving an account of the creation of the heavenly bodies, the expressions of Moses are evidently accommodated to the first, and familiar notions of mankind, derived from the sensible appearances of the earth and heavens, so throughout the whole history of the creation, the leading object seems to be, not to tell us by what particular process the various bodies around us came into existence from nothing, but to let us know in language the best fitted for the purpose that could be employed, that it was by successive exertions of Almighty power, that the earth was brought into its present form and condition—a truth which the discoveries of geology abundantly establish.

It is supposed to be the opinion of every respectable living geologist, that the earth had existed, and been inhabited by living creatures, and subjected to various catastrophes and changes, many thousands of ages before the creation of man. But all those more ancient transactions and events are omitted in the history. In the first verse of Genesis the general proposition is enunciated, that the heavens and the earth are the workmanship of the Divinity. The sacred writer, passing over myriads of centuries, then comes down at once to the era, when at the close of some mighty revolution that had just occurred, when "the earth was without form and void," God was about to descend once more in creative energy upon our planet, to reform its disorders, rebuild its desolations, and especially to give being to that nobler race of living creatures, for whose instructions this record was drawn up. The narrative is here resumed, and in giving an account of the transactions of six successive days, he appears to mingle with that particular history, some notices of events of a far more ancient date; just as in the prophecies, reference is had in the first instance to occurences soon to take place, and afterwards to others of greater importance, in which, the prediction is to receive its full and perfect accomplishment.

If any one then shall raise an outcry against geology, as hostile to the truths of Revelation, he will only make it evident that he shares the ignorance and folly of the inquisitors who dictated to Galileo the celebrated confession, in which he renounces the doctriue that the sun is immoveably fixed in the heavens and the earth in motion, as a pestilent heresy.

"I, Galileo Galilei, son of Vincent Galilei, by birth a Floren-"tine, aged seventy years,—declare; that inasmuch as the Holy "office had in a regular and lawful manner enjoined upon me to "abandon the false opinion that the sun is the centre of the system "and immoveable, and that the earth is not the centre of the uni-"verse, and that it is in motion, and inasmuch as I ought not "afterwards to have either held, defended, or taught, this doctrine, "in any manner whatever, in conversation or by writing, and not-"withstanding, after it had been declared to me that the aforesaid "doctrine is contrary to the Holy Scriptures, I have written and "caused to be printed, a book, wherein I treat of that condemn-"ed doctrine, and bring arguments of great weight in favour of it, "without giving any refutation of them, I have therefore been "adjudged to be strongly suspected of heresy, and as having be-"lieved that the sun is in the centre of the universe and motion-"less, and that the earth is not the centre, and that it moves— "therefore, wishing to remove from the minds of your Eminen-"ces, and of every orthodox Christain, this violent suspicion, "with such good reason entertained against me, with a sincere "heart, and faith unfeigned, I abjure, condemn, and detest, the "above mentioned errors and heresies, and I swear, that in fu-"ture I will not say or affirm anything, either in conversation or "by writing, which shall afford ground for such suspicions "against me."

Such was the humiliating abjuration exacted of Galileo, of an opinion now regarded by the whole civilized world, not only as harmless, and consistent with a sincere attachment to the Christian faith, but as the only one that can be entertained by person of a sound and enlightened mind ; and the objection raised against it was, that it seemed to be at variance with the literal meaning of the sacred writings. Such are the consequences of supposing that what we may regard as a literal interpretation of the language of the scriptures should interfere with the freedom of philosophical inquiry.

OF TERTIARY FORMATIONS.

56. A principal source of the errors into which men have fallen, and of the unsound doctrines they have embraced in the science of Geology, is to be found in their assumptions respecting the *age* of the earth, which has very generally been held not to have existed more than a few thousands of years. The creation of man, was supposed to have been immediately consequent upon that of the soil on which he was to tread, and as the descendants of Adam are given in regular succession, down to the date to which profane history ascends, a reverence for what was supposed to be recorded as true in the sacred volume, shackled the spirit of free enquiry. And even after it was observed that without abandoning our belief in the divine origin of the scriptures, or rejecting any of the statements contained in them, we may assign a greater antiquity to the earth, men were slow in appropriating the eternity which we know must be already past, to the production of the changes that the crust of the globe has evidently undergone. As in the first attempts at navigation, it was a small arm of a bay, or a river, that was passed, next there was a tedious and winding voyage along the shore, and always within sight of land, and it was not till ages had elapsed, that the mariner learned to commit himself fearlessly to the broad ocean —so, when it began to be generally admitted that the earth had existed, and been the dwelling place of living beings, prior to the creation of man, geologists seemed filled with a strange apprehension and dread of the past eternity, and contented themselves with the opinion that the earth might be some few centuries or thousands of years older, than had been previously supposed. They were fearful of embracing the idea that the earth though not eternal, might be of an age, in comparison with which, the existence of man upon its surface sinks into insignificance. The tendency of modern discoveries in geology has been, to enlarge immeasurably the supposed term of its past duration.

We have heretofore given the names, and the order of succession, of a long series of secondary strata, occupying the south-eastern part of England, (Sec. 29,) and stated that the races which are entombed in the oldest of these strata must have differed widely from such as now inhabit the earth ; but that there is a gradual approach in the more recent strata, to the type of such as are found living in the existing oceans. The most recent of the *secondary formations* is the *chalk* that presents itself so conspicuously in the cliffs of Dover to a person who is approaching the island from the southeast. It abounds in organic remains, but until recently was supposed not to contain *a single species* that is known to inhabit the earth at the present time. Since the deposition of the chalk therefore, it appeared that the population of the earth had undergone a total change, not only in regard to the *individuals* occupying it but in regard to *species*.

Above the chalk, in Messrs. Conybeare and Philips' Outlines of the Geology of the country, there are noticed and described three or four formations in the neighbourhood of London, and upon, and near the Isle of Wight, of limited extent, where the species now inhabiting the ocean begin to make their appearance; at first or in the lower beds; rarely, and mixed with a large number of extinct species, but afterwards in greater variety. Here then the line of demarcation was drawn between the secondary and tertiary strata, the former, being such as contain *extinct species only*, the latter, an intermixture in larger or smaller numbers, of *species that are recent or still living*.

Very recently, Ehrenberg, employing the microscope in these investigations, has ascertained that a great number of shells, mostly too small to be accurately distinguished by the naked eye, are common to the chalk and the more recent strata. But the line of separation here indicated, will probably not be changed on that account.

It was formerly held that the deposition of the chalk, the newest of the secondary strata, was an event of comparatively recent occurrence, and if not actually within it, approaching the borders of our own time. This opinion is now abandoned, and the chalk referred to an era exceedingly remote; separated in fact from the present day, by ages, compared with which the period embraced by human records whether sacred or profane, is but a brief and evanescent term of duration. We have now to state the facts and observations on which these new views and doctrines are founded.

The tertiary district that first attracted particular notice is that which surrounds the city of Paris, embracing an area of about 7100 square miles, equal to the one seventh part of the state of North Carolina. It is commonly called the Paris basin, that city being nearly in its centre. It is surrounded by chalk on every side except the south, and southwest, in which directions that formation is wanting, and the tertiary beds rest upon the strata underlying the chalk.

When a new impulse was given to the study of Geology at Freyburg, the attention of Werner and his disciples was directed principally, and with the most interest, to the more ancient rocks. To these succeeded as objects of study and investigation, the secondary strata, especially those of England. It was not till the publication of the "Mineralogical Geography of the Environs of the city of Paris," by Cuvier and Brongniart, in 1811, that the highly interesting character of the tertiary strata began to be appreciated and understood. Those occupying the Paris basin were represented by these philosophers as admitting of four great divisions, and these of certain smaller subdivisions.

1. Immediately upon the chalk reposes a stratum of marine origin, with some intermixture of freshwater beds. The most important member of this division is a coarse limestone, abounding in shells, in excellent preservation. It is about ninety feet in thickness, and as some parts of it afford a building stone of good quality, numerous quarries have been opened in it beneath and around the city of Paris.

2. Next in order, is a freshwater formation, consisting of beds of gypsum and gypseous marl. It is remarkable chiefly as containing near its upper surface, the remains of several genera and species of Mammalia that no longer exist upon the surface of the globe, the successful study and determination of which have immortalized the name of Cuvier.

3. There succeeds a stratum of sandstone, the lower beds of which are without organized remains of any kind, but those higher up, abound in shells belonging to races that inhabit the sea.

4. Covering all these is a second freshwater formation of very variable mineralogical character, presenting in some parts a soft friable limestone, and in others the hardest siliceous minerals, as jasper and buhr millstone.

The order of superposition of these deposits was represented to be such as has just been stated, but they all rise to the surface in places, as along their edges, or where they have been laid bare by the removal of the mass of material lying above. The shells had been previously studied and illustrated with wonderful zeal and ability by Lamarck; the bones of the Mammalia attracted the attention of Cuvier about the year 1800, and gave origin to the investigation by Cuvier and Brongniart, the results of which have just been exhibited. Succeeding observers have proposed some modifications of the scheme of classification, especially in the first and second of these assemblages of strata, which are now supposed to have been nearly contemporaneous.

As the investigations just noticed, were conducted with great skill and ability, and the published report of them was very full, filling nearly 300 quarto pages, the strata of the Paris basin became a sort of standard to which other strata bearing any resemblance to them, discovered in other countries, were referred. Such strata exist in England, on both sides of the Thames, above and below London, and upon the Isle of Wight and in its neighborhood, but of much greater extent and importance in Italy, on both sides of the Appenines.

It would appear that what now bears the name of Italy, was at the time of its first emergence from the deep, but a long narrow ridge, consisting indeed merely of what is now the Appenines, with a sea of moderate depth on each side. On the flanks of these mountains, races of shell-fish came into existence, lived and died, accumulating the materials for tertiary strata of great extent and thickness. The power which had elevated the Appenines now became active a second time, and Italy rose from the waters co-extensive with its present limits. Corresponding remarks may be made respecting the island of Sicily, in the southern part of which, the tertiary strata have been lifted to the height of 3000 feet above the level of the sea.

But when the shells from the Paris basin, from the sub-Appenine deposits, and from the south of Sicily, were compared with each other, and with recent or living species, a wide difference is observed amongst them. In the Paris Basin, nearly all the species collected and determined, amounting to more than a thousand, (1238,) are now extinct, only 42 of the whole number being still living. The proportion of living species, is that of three and a half in an hundred, nearly. On the Loire, in the south of France near Bourdeaux, in Piedmont, and in the basin of Vienna, in which places there are tertiary deposits, the proportion is about eighteen in a hundred. In the sub-Appenine beds, from a third to a half of the species are still alive in the waters of the Mediterranean, though they are generally more numerous in seas nearer the equator, and attain a larger size there, indicating that a tropical climate, where its increase and development is greatest, is the appropriate habitat of the species; and as the shells dug up in Italy are also larger than those that now cover the living animal in the Mediterranean, it is inferred that the climate of that country was formerly hotter than it is at present. Finally, the shells obtained in the southern part of Sicily, and sometimes on the tops of mountains of considerable elevation, agree, with few exceptions, with such as are found in the neighbouring seas at the present day.

The general inference drawn from these facts, is, that the strata of the Paris basin, of the basin of Vienna, of the sub-Appenine, and of the south of Sicily, are not only not contemporaneous, but separated from each other by immense intervals of time. Between the era of the Paris basin and of that of Vienna, a period intervened during which not merely individuals, but whole species perished and became extinct, and others were created to supply their places. A corresponding lapse of ages separates other tertiary deposits that differ in the same manner from each other, in the number of the living species they furnish. Nor does it appear that the genera or species which perished were swept away by any sudden and violent catastrophe. Either some unknown casualty brought the existence of the different races one by one to its close, or perhaps every species receives into its constitution at its creation, the seeds of decay and dissolution, along with the principle of life, so that the period during which it is to inhabit the earth, is circumscribed by certain definite limits.

That geologists may be furnished with convenient names by which to mark and designate in their publications and communications with each other the periods during which the strata we are now considering were deposited, the following terms, which have come into pretty general use, and are of frequent occurrence in the recent works on geology, have been proposed by Lyell.

1. For the earliest of the periods we have noticed, that during which the strata of the Paris basin were deposited, he has proposed the title of *Eocene*, from ἠως aurora, and καινος, recent, or new, because the extremely small proportion of living species contained in these strata, indicates what may be considered as the first commencement, or *dawn* of the existing state of the animate creation.

2. The next following epoch he names *Miocene;* from μειων, minor, less, and καινος; a minority only of fossil shells embedded in the formations of this period being of recent species; a little less than eighteen in one hundred. The south of France near Bourdeaux, Piedmont, and the basin of Vienna, are examples of Miocene formations.

3. 4. To the strata of Italy and Sicily are appropriated the designations of older and newer *Pliocene;* from πλειων, major, greater, and καινος, indicating a nearer approach and more intimate resemblance to the existing population of the ocean. A part at least of the Low Country of North Carolina; perhaps the whole, (a few isolated rocks excepted,) belongs to the Pliocene period.

From the statements just made, it will appear, that since the era when the deposition of the tertiary strata commenced, geological formations have been of limited extent. The materials of which they are composed are accumulated during an indefinite period in the bottom of the sea; the causes of geological phenomena that had apparently been slumbering for ages then awaken to new activity, and a tract of greater or less extent is raised above the waves, and added to the previously existing continents. It is in this way, and not by the gradual accretion and extension of its shores, that the Low Country of the United States has been gained from the ocean.

57. Prop. VIII. *Since the tertiary strata were deposited, and since the creation of the existing races of brute animals, and of man, one great catastrophe has changed the face of the earth. A flood of waters has covered those parts of the earth's surface which had previously been and are now dry land.*

The appropriate demonstration of the truth of this proposition is furnished by the Holy Scriptures. Of the truth and credibility of the statements contained in the scriptures, the well authenticated miracles recorded in them furnish ample proof, shewing as they do, that this one book is a revelation from the most high God.

The belief has been fondly entertained by some persons, that evident marks and traces of the deluge are still visible upon the surface of the globe, and they would bring in physical, to aid in the establishment and support of theological truth. But even if we discover the effects of an ancient inundation, and the ravages produced apparently by a flood of waters in motion, it will be difficult to prove that they are to be referred to that particular catastrophe of which Moses has furnished us with a brief history, and not to some other one of those great revolutions that have changed the face of the earth.

It is probable that natural science will be compelled at length to confess her utter ignorance on all points connected with the subject of revealed religion, and to acknowledge that her testimony is altogether of a negative character, that she can offer nothing decisive either for or against it. The facts that have been supposed to have a bearing upon this question, and an abstract of the conclusions drawn from them, are now to be exhibited.

All the shells, of whatever age or kind, that are found far inland, on the summits, or imbedded in the strata of mountains, were once adduced as proofs of Noah's deluge. Not one person held entitled to the name and character of a philosopher takes this view of them now. They existed, and nearly in the places where we find them, millions of ages before Adam was created. But the recent beds of sand, loam, and gravel, sometimes enveloping the remains of various animals, that present themselves in many different parts of the world, are still referred by some geologists to the deluge, and considered as furnishing satisfactory evidence of the occurrence of such an event.

They are not known to exist in North Carolina, but are of frequent occurrence, though generally without organic remains, in the Northern and Western States, and with remains imbeded, on the Island of Great Britain, and the Continent of Europe, and in the northern part at least, of the Continent of Asia. The appearance of these accumulations of loam and gravel, the nature of the pebbles found in them, and the circumstances under which the bones exist in them, (at considerable depths, and not upon the surface, where the bones of such animals are left, as perish by disease, or are killed by other species,) prove that the whole mass has been produced by a flood of moving waters. Nor is it a valid objection to this inference, that we may be unable to assign the cause, either proximate or remote, by which such an inundation may have been produced, and the waters set in motion, those cases being of frequent occurrence in Geology, where we are certain that events have taken place, whilst we are unable to specify the agent and method by which they have been accomplished. Some of the theories however that have been proposed for accounting for the deluge by the operation of natural causes, are entitled to a passing notice.

Amongst the bones which are found imbeded in *diluvium*, (for by this name the sediment or mud of the deluge is distinguished from the alluvion of rivers) are those of the elephant, which have been dug up in all parts of the world. It is in Asiatic Russia that they occur in the greatest abundance. Pallas says that from the Don to Kamschatka there is scarcely a river whose bank does not afford remains of the mammoth or elephant. The bones are generally dispersed, seldom occurring in complete skeletons. It was long denied that they are the remains of the elephant, and asserted that they are lusus naturæ, bones of giants, skeletons of fallen angels, &c. When there could no longer be any doubt on this point, a new difficulty arose. But two living species of elephant are known ; the Asiatic and the African, both of which are inhabitants of a warm climate. But the bones in question are found in the greatest abundance along the northern border of the empire of Russia, a region locked up in eternal frost. The quantity of the ivory furnished annually to the arts by that quarter of the world is by no means inconsiderable.

These facts suggested one of the celebrated theories of the deluge; that namely, which attributes it to a change in the position of the earth's axis, and represents that the antediluvian world spun around an axis terminating in the main Atlantic and Pacific oceans, so that northern Asia, and the eastern part of Africa, belonged to the equatorial regions.

This theory is refuted by a number of independent arguments. An experiment furnished by the whirling-table is alone decisive. It proves that a yielding body revolving rapidly, assumes the figure of an oblate spheroid. The earth has this figure, the shorter diameter being along its present axis. We formerly inferred, (sec 43), that the earth assumed its present form at the creation, or when it was in a fluid or semifluid state, in consequence of its motion on its axis. If the axis of revolution had been changed subsequently ; after the consolidation of the rocks ; though the water would flow towards the new equator, the solid crust would have become too rigid and unyielding to accommodate itself accurately to the new condition of the forces acting upon it. The earth must therefore have revolved before the deluge, in the same manner as at present, and the position of its axis can have undergone no change at that time.

But further ; the fossil elephants whose remains are so extensively distributed over the globe were of species different from any that now exist, and one species at least was fitted to inhabit a cold climate. The bones themselves show that they belonged to species that are now extinct. About the beginning of the present century, an individual that must have been frozen up soon after its death, was disengaged by the melting of the ice in which it had been enveloped, from a high bank near the mouth of a river in the north of Siberia. The Indian and African elephants are naked. This was furnished with three kinds of hair : one was stiff black bristles a foot or more in length, a second, thinner bristles or coarse flexible hair of a reddish brown color, and the third, course reddish brown wool, which grew among the roots of the long hair. More than thirty pounds weight of the hair and bristles was gathered from the wet sand bank into which they had been trampled by the white bears whilst devouring the carcass. This warm and abundant covering indicates, that Siberia was the same cold and frozen region before the deluge as at the present day: in other words that the position of the earth's axis has not been changed.

Burnet represented that the earth consisted originally of a thin crust covering an abyss of water; which crust was broken up for the production of the deluge, and formed the mountains by its fragments. Woodward held that this catastrophe was occasioned by a temporary suspension of the attraction of cohesion; the whole mass of the globe was reduced to a soft paste which became penetrated by shells. Deluc's opinion was, that the sea now occupies the situation of the ancient continents, and that what is now dry land, was, antecedently to the deluge, the bed of the sea. That event was therefore produced by the subsidence of what had been the most elevated parts of the crust of the earth, and the elevation of those which had been the lowest.

58. Dr. Buckland, Professor of Geology in the University of Oxford, refuted all these different hypotheses and others with them, at once, and proved that what is dry, inhabited land now, was dry, inhabited land before the deluge: also that at an era that is comparatively recent in the history of the earth, England was the abode of those races of animals which are seldom found at the present day, if ever, beyond the limits of the torrid zone.

In the summer of 1821, some workmen who were engaged in carrying on the operations of a large limestone quarry in the side of a hill near the village of Kirkdale in Yorkshire, Eng., accidentally intersected the mouth of a long hole or cavern, closed externally with rubbish, and overgrown with grass and bushes. The bottom of the cavern was covered to the average depth of about a foot, with a bed of soft mud or loam. None of this sediment was found attached to the sides or roof. It was itself covered over with a plating of stalagmite, or that calcareous matter which often forms an incrustation on the sides and bottom of limestone caverns. There was no alternation of layers of stalagmite and loam, but beneath the loam, there was another coating of stalagmite, reposing upon and covering the bottom of the cavern. On breaking through the upper covering of the sediment, and digging into it, it was found that all the lower part of it, and also the stalagmite beneath, held enveloped an immense quantity of small fragments of bone. The workmen at first supposed them to have belonged to cattle that died of a murrain in this district a few years before, and they were neglected, and thrown upon the roads with the common limestone. At length however they attracted attention, and were found to include the remains of no fewer than twenty three different species of animals—the Hyena, Tiger, Bear, Wolf, Fox, Weasel, Elephant, Rhinoceros, Hippopotamus, Horse, Ox, three species of Deer, Hare, Rabbit, Water-Rat, Mouse, Raven, Pigeon, Lark, Snipe, and a small species of Duck. The bottom of the cavern, when the mud was first removed, was found strewed all over like a dog-kennel, from one end to the other, with hundreds of teeth and bones of the animals just enumerated. They were found in the greatest quantity near its mouth, because it was widest there.

Those of the larger animals, the Elephant, Rhinoceros, etc., were found co-extensively with the rest, in the inmost and smallest recesses.

Here a difficulty may arise in the mind of the student to whom the subject is new. How is it possible amongst such a mass of fragments of bone, to distinguish those of a particular animal, or to determine that the remains of 23 different species, are associated in the same cave? It is no part of our purpose to deliver instructions in comparative anatomy, but some general ideas may be given of the manner in which the investigation, (prosecuted with more zeal and success by Cuvier than by any other individual), is carried on.

It is evident on the slightest consideration of the subject, that animals differ in their osteology, not much less than in their external appearance. The skull of an ox will be distinguished from that of a horse, by a person of the most ordinary capacity, and with nearly as much ease, as the living animals themselves to which they severally belonged. On a more careful examination, a marked difference would be apparent, between the bones of the limbs, as well as those of the head. It is also evident that the dissimilarity in the bones of the limbs must be far greater, when herbivorous and carnivorous animals are compared; the horse for example with the lion. The legs of the horse are fitted for motion in one plane, from which there is never any very great deviation. In those of the lion there is required a freer motion, that he may leap and bound in any direction, and bend his paws for the seizure of his prey. Any intelligent person, with some experience in this kind of investigation, would determine from the articulations of the joints, to which of the two races an animal whose bone he held in his hand had belonged. But by those who have made comparative anatomy their particular study, it is found on a minute examination; that the skeleton not only of each great class, but of every genus and species, has peculiarities of its own, and that these peculiarities extend through the whole frame, so that it is asserted that with a single bone before him, a skilful anatomist, will be able to reconstruct the animal. If it belong to a species still living on the earth, he will be able to designate that species. If it belongs to a species that is extinct, the anatomist will be able to determine its genus, and he will then proceed to erect it into a new species. If it belong to an extinct genus, he will determine its order, and erect it into a new genus.

Some exaggeration it may be either suspected or fully believed there is, is these representations, such as it is difficult for a mind warmed with the enthusiasm created by new and important discoveries to avoid altogether, but the consent of the Naturalists of all countries, proves the great principle asserted in them to be correct and true—that the figure, and manner of life, of a race of animals long since extinct, may be ascertained from the form and structure of their bones.

The science of comparative anatomy has been brought to bear upon the animal remains found in the Kirkdale cave, and it appears that the bones of the 23 species mentioned, are mingled together there.

That the drift and bearing of what is immediately to follow, may be the better understood, it may be well to state before proceeding farther, the conclusions at which Dr. Buckland arrived respecting this cave—that it was the den of a species of antediluvian hyena, and that the bones it contains, are the remains of the animals which the hyenas dragged into it for the purpose of eating them there.

The three living species of hyena now known, differ somewhat in their habits, but that which is most common, inhabiting Abyssina, and other hot countries, preys upon dead carcases, which he devours even to the bones. He sleeps during the day, and prowls about the cities and villages at night, carrying off to his den, any dead animals he may happen to find. He descends into the graves and feeds upon human bodies. His jaws are more powerful than those of any known animal of nearly equal size. Dr. Buckland saw the keeper feed one that was carried for exhibition through England. He gave him bones. The shin bone of an ox he first gnawed at its upper part, and then broke into splinters which he swallowed whole, leaving the hard and solid part below the marrow untouched, the shin bone of a sheep, he broke into two pieces, and then swallowed without any mastication.

From this account of the habits of the hyena, we revert to the contents of the cave. It has been stated that immense quantities of bony fragments were found enveloped in the loam, or in the stalagmite. These consist of the harder parts of the skeleton to which they belonged. On many, there are marks which correspond exactly to the hyena teeth that lay strewed over the floor of the cavern. The *teeth* of the various animals were also found in great quantities, so that the number of the teeth, and of the solid bones, of the tarsus, and carpus, was more than twenty times as great as could have been supplied by the individuals whose other bones were found mixed with them. One gentleman collected more than three hundred canine teeth of the hyena, which must have belonged to at least, seventy-five individuals, and adding to these the canine teeth derived from the same spot, that are in other collections, the whole number of hyenas of whose existence here there is evidence, cannot be estimated at less than two or three hundred. When this fact is viewed in connexion with the marks of teeth upon the bones, still remaining, and we consider further that the cave is so small that it is impossible that an elephant, a hippopotamus, or a rhinoceros, can have entered it; it is difficult for a candid man to refuse an acquiescence in the conclusions of Buckland—that this cave is a den of antedeluvian hyenas, who brought the bones into it for the purpose of feeding upon them. If so; it follows that the northern part of England was dry land before the flood, and it becomes very probable that the same is true of the greater part of the existing continents. Caverns containing bones associated a good deal in the same way, though not in equal quantities, are found in France and Germany. We may suppose therefore that the deluge destroyed the inhabitants, without altering greatly the external features of the earth.

ANCIENT ZOOLOGY.

59. The ancient, appears to have been more favourable than the present condition of the earth, to the development of certain forms of animal life. The largest living lizard is the crocodile of the Nile, which when full grown, is from twenty-five to thirty, and individuals have been seen that were perhaps forty feet in length. The Megalosaurus, or Great Lizard, whose bones are imbedded in the strata of Stonesfield, twelve miles from Oxford, England, exceeded by one-third, the largest crocodile. The bones of the Iguanodon, (so called from the structure of his teeth, resembling those of the Iguana, a lizard inhabiting the West Indies, and indicating that he was herbivorous,) have been found in such numbers, in the south-eastern part of England, in Kent, and Sussex, as to furnish data for calculating the average size of this reptile. His length must have been upwards of sixty, and it is supposed that some individuals may have reached an hundred feet.

Both these are from secondary formations: but it is the tertiary strata that afford the most ample materials for instituting a comparison between the zoology of the ancient, and that of the present earth.

In the Eocene strata of the Paris Basin, the remains of *Mammalia* are found in great quantities—first, or lowest, the marine races, dolphins, lamantins, and morses, and higher up, in the gypsum, terrestrial quadrupeds of the same family, but of extinct genera and species. The extinct genera detected and brought to light by Cuvier, received from him with reference to certain characters they were found to present, the names, of Palæotheriun, Lophiodon, Anoplotheriun, Anthracotheriun, Chœropotamus, and Adapis. The remains of extinct species of existing genera, indicate a great variety and abundance of animals of the order Pachydermata, including the elephant, rhinoceros, tapir, and camel.

MINERAL GEOGRAPHY.

60. By reason of its connexion with other interesting subjects of enquiry, the distribution of the rock formations, and of valuable mines, over the surface and through the crust—the Mineral Geography of the earth, merits a place in a course of liberal study. But to the acquisition of this kind of knowledge, some acquaintance with the principles of Geology is indispensable. It is of little use that we be informed that the rocks of a country, are granite, or sandstone, so long as we are ignorant what those substances are ; and what the characters are, which they impart to the scenery and the soil of the region where they prevail. The progress of nations in population, the arts, and wealth, have in all ages been greatly influenced ; and in many cases, the genius, character, and pursuits, of a people determined by the nature of the rocky strata beneath and around them. Civilization and refinement appear to have commenced on the tertiary formations. The fertile and easily cultivated alluvial plains of the Euphrates, and the Nile, were selected for permanent settlements by the early inhabitants of the earth, whilst the rugged and barren primitive and transition mountains, were visited only by hunters in pursuit of game. The Greeks would have made little progress in the arts of architecture, statuary, and painting, had the rocks of their country been granite, instead of marble. The relative position of Great Britain amongst the nations of Europe, in regard to wealth, and power, depends very much upon the geological character of the strata of that island, and especially the number, extent, and riches, of her coal fields.

Africa. The northern shore of Africa appears to be covered by secondary and tertiary deposits. The ridge of Atlas consists in part of primitive rocks, but their range and extent are not known. The substratum of the great desert of Sahara, is principally a red sandstone of unknown age. The succession of the geological formations that is met with as we descend the valley of Egypt, (granite, sandstone, and limestone,) has been already given (Sec. 35.) In Abyssinia, the predominant rocks appear to be gneiss, clay-slate, and the products of volcanos. A range of primitive mountains stretches across the continent near its broadest part. Southern Africa is not characterized by the prevalence of rocks of any age, to the exclusion of others, but granite, slate, and sandstone, appear at the surface in succession, at moderate distances. A considerable quantity of gold is collected on both the eastern and western coasts, but with this exception, the valuable minerals known to exist in Africa, are few, and unimportant. Mineral coal has not yet been observed in any part of the continent.

Asia. The great central nucleus of southern Asia, the Himmaleh mountains, is granite, and sends off spurs of the same character in different directions ; as into Indostan, in the direction of Cape Comovin, three-fourths of that peninsula, and the whole of Ceylon, being occupied by primitive rocks; through Birmah, down into the peninsula of Malacca, which abounds in stanniferous granite; and finally into China. The tract along the shore of the Arctic ocean is tertiary. About the Caspian is a volcanic region. East of this are the sterile, secondary, plains of Tartary, abounding in salt, and farther still; between the longitudes of 70°, and 90°, another seat of volcanic action. The rocks of Palestine are mostly secondary limestone, but around the sea of Tiberias, and the Dead Sea, (whose surface is 1343 feet below that of the ocean) are some of volcanic origin. Mount Sinai is a mass of granite. Of the central regions of Asia, we know hardly more than of those of Africa. There are several rich mining districts within the limits of this continent; three within the limits of the Russian Empire, indicating the existence of primitive and transition rocks, along the southern confines of Siberia, and others near the south-eastern coast. The Ural mountains are rich in iron, copper, gold, silver, and platinum, especially on their eastern or Asiatic side. That part of the Altaian mountains from which flow the head waters of the Irtish, contains an abundance of the same metals, (platinum excepted,) but especially of silver. The third district is that of Nertschink, southeast of the lake Baikal. Some of the finest specimens, as well of the earthy minerals, as of the ores of these metals, that give beauty to the cabinet of the mineralogist, are from Siberia. South-eastern Asia yields the precious gems; India beyond the Ganges, the ruby, and sapphire; Indostan and Borneo, the diamond. The peninsula of Malacca, and the island of Banca, contain inexhaustible stores of tin; nearly all the antimony of commerce comes from Borneo.

Europe. A large part of Europe is covered by tertiary deposits. This is true of Holland, the kingdom of Hanover, Prussia, Poland, and much of Russia, but near the southern border of all these, except Holland, rocks of an earlier period make their appearance. Sweden and Norway are mostly primitive, and from their southern extremity, we may suppose the elevated edge of a basin, of the same character, and including the central states, to be continued under the sea, through the western part of Scotland, England, and Ireland, the provinces of Brittanny and Auvergne in France, the Alps, and ancient Mœsia, and Thrace. Much of Bohemia is also primitive. The same secondary and tertiary strata which occur at low levels, and in a horizontal position, in England, are elevated and inclined at high angles, along the sides of the Alps, proving that these mountains have risen to their present height, since the secondary strata of England began to be deposited. But of the mineral geography of the different kingdoms of Europe, a more particular account must be given.

Ireland. Groups and ranges of primitive and transition moun tains extending nearly round the island, inclose a central district of secondary formations. More than one-seventh of its surface is covered by bogs of turf, or peat, from 5, to 30 feet in thickness. As the coal of Ireland is neither abundant nor good, peat is generally employed by the inhabitants for fuel. Most of the bogs are in the midland counties. In the northern part of the island, is a body of basalt, covering an area of 800 square miles, one of the beds of which having formed in cooling an assemblage of regular fissures, constitutes what is called the Giant's Causeway. The pieces of silicified wood that are found in, and about, Lough Neah, have given origin to the fable that the hones in common use, are manufactured, by cutting pieces of hickory, so as to be composed partly of sap, and partly of heart wood, and immersing them in its waters. Gold has been found in Ireland, also small quantities of lead, and zinc, and a larger amount of copper ;—the latter especially at Allahies in the county of Cork, but the mineral wealth of this island is not very considerable.

Scotland. Nearly the whole of the northern part of this kingdom, comprehending the Highlands, and the isles, is occupied by the most ancient primitive rocks; granite, gneiss, and mica slate, which at some points are covered by formations of sandstone, and at others give place to more recent rocks, of igneous origin. In its southern part, are transition strata, and between the two, are extensive coal formations, extending across the island, on both sides of the Clyde and Forth, and the principal seat of the manufacturing industry of Scotland. The coal is accompanied as in England, by clay iron stone, giving rise to important establishments for the manufacture of iron. The lead mines of Lanarkshire, are inconsiderable in comparison with those of England, Spain, and the United States.

England. The more recent strata in the middle and south-eastern counties, from the old red sandstone upwards, have been sufficiently noticed and described. The older rocks are in the west, and the oldest primitive are rare. In the granite and schist of Devonshire, and Cornwall, but especially in the latter county, are very productive mines of tin, and copper. The lead mines are mostly in the northern counties, Northumberland, Cumberland, and Durham ; also in Derbyshire and Flintshire, in the oldest secondary limestone and the associated beds, which also yield considerable quantities of zinc, and manganese. Iron, copper, tin, lead, zinc, and manganese, are the metals furnished to commerce by the mines of England.

France. There is a large body of primitive rocks in the North-western corner of France, in ancient Brittanny, and on the lower waters of the Loire ; a second in the Pyrenees ; a third in the centre of the kingdom, amongst the head waters of the Loire and the Garonne—the seat in ancient times of volcanic action ; a fourth along the western declivities of the Alps—and a fifth, which is of small extent, in the Vosges, near Strasburg and the

Rhine. Winding amongst these, embracing them, and interlocked with them, and with each other, in various ways, are the formations of more recent date. The tertiary deposits of the Paris basin, and of the Garonne, have been mentioned. Another is remarkable for occupying a depression in the central primitive plateau, upon which it reposes directly, without the intervention of any other rock. Mines of iron, lead, copper, and antimony, are wrought in several different places, in or near the primitive formations, but with the exception of antimony, the metal obtained is not sufficient to supply the wants of the kingdom.

Spain and Portugal. Less is known of their geology, than of that of any other part of Europe, Turkey excepted. Ranges of primitive mountains extend through the central parts of the Peninsula; the province of Galicia is also primitive. But the Cantabrian chain, on the north, and the Sierras Morena and Nivada in the south, are formed of more recent rocks. There is an abundance of excellent iron ore in the province of Biscay, and coal in Asturias; but the part of Spain most favoured by nature, is that lying within the limits of the ancient kingdom of Granada. Here are the quicksilver mines of Almaden, in clay slate, yielding a greater amount of that metal than all the other mines of the world, and the mines of Adra, which fix the price of lead throughout the continent of Europe.

Switzerland. Its granite, and secondary limestone mountains (Jura) have been mentioned. A tertiary formation called by the Swiss geologists (the molasse) extends from the lake of Geneva, in a north-easterly direction, to that of Constance. There are salt mines at Bex.

Italy. Except near its northern extremity, and in the neighborhood of the Alps, there are no primitive rocks in Italy, nor has it any valuable mines. The Appenines are a ridge of secondary limestone, with tertiary deposits on each side; Corsica, Sardinia and Elba, are mostly primitive, and the latter has been celebrated from a remote antiquity for its mines of iron. The greater part of Sicily is of recent origin. It is from the Solfatara near Naples, and the tertiary blue clay of this island, that Europe is supplied with sulphur.

Germany—Central Europe. The shores of the North Sea, and the Baltic, to a considerable distance inland, are low and level tertiary deposits. Throughout the greater part of Belgium, the whole of Holland, Hanover, Denmark, the northern part of Prussia, including more than half of the kingdom, Poland as it was before its dismemberment, and much of European Russia, we find tertiary clays and sands, of very different composition, and unequal fertility, in different places, but bearing everywhere a considerable resemblance to the low country of North Carolina. There is probably a greater extent of sterile soil in Prussia, than in any other part of this area.

South of the tertiary, the older rocks come in, forming one of the rich mining districts of the world. The most of Bohemia and Saxony is primitive. Southern Belgium has mines of zinc, lead, and copper : the Hartz yield iron, lead, silver, copper, zinc, and manganese : Saxony and Bohemia, silver, lead, cobalt, tin, copper, iron, arsenic, and bismuth : Silesia, iron, zinc, arsenic, silver, lead, and copper. Of the Austrian possessions ; Hungary affords the precious metals, lead, copper, and tellurium : the southern provinces, (Styria Carinthia and Illyria) iron, zinc, quicksilver, lead, and copper. The amber of commerce is brought from Prussia, and is either thrown up by the Baltic, or dug from the earth, at no great distance from its shores.

Sweden and Norway are mostly primitive. They furnish copper ; and iron, of the very best quality that is made. The Swedish iron is imported into England, and employed to the exclusion of every other in the manufacture of steel.

America. Our knowledge of the geology of the western continent, is of course limited and imperfect. The primitive rocks have attracted attention by the peculiarities of their composition and structure. The relative extent of surface occupied by them, appears to be rather greater here than in the other quarters of the globe. Interspersed amongst the primitive, and covering them, formations of more recent orgin, slates, and fragmented strata, are widely distributed, but little is known of their position, or their age, as compared with the transition, secondary, and tertiary, beds of England, France, or Germany. A range of mountains extends through the whole length of the continent, the depressions being greater where the land is narrowest, (in Central America) than elsewhere. At a number of points, it is, or has been, the seat of volcanic action. The fundamental rock of both the Andes and the Rocky Mountains, appears to be some one of those that are called primitive, and especially granite, but these are covered by others of more recent date—porphyry, obsidian, trachyte, whose igneous origin is undoubted. It is on the flanks, or near the summit of this great mountain range, or where it spreads out into a body of table land, that the mines of the precious metals for which America is so much celebrated occur. Chili yields silver, and a great abundance of copper ; Bolivia and Peru, silver, gold, and mercury ; Central America, gold and silver, and Mexico the same, but especially silver. Brazil which is widely but not exclusively primitive, is famous for the value of the precious stones rather than of the precious metals, that it sends into the market of the world.

United States. Five principal formations require notice within the settled parts of our country. 1. The Primitive, covering nearly the whole of New England, and extending from thence through New York, New Jersey, Pennsylvania, near Philadelphia, and Maryland (in which state it is narrow) central Virginia, North Carolina, South Carolina, and Georgia, into Alabama. It is also continued northward beyond the limits of the United

States, across the lower waters of the St. Lawrence, into Labrador, and is covered by No. 5 through a distance of about thirty miles, north of Trenton, in New Jersey, so as to form at the surface two separate bodies of rock. 2. West of this is a transition formation, commencing in Canada, occupying the western part of Vermont, embracing as it advances towards the south-west, the larger part of the Alleghany mountains, but not extending much beyond them, and containing in Pennsylvania immense beds of anthracite coal. 3. Farther west still, are the secondary strata of the valley of the Mississippi, through which the primitive Ozark mountains protrude, in the states of Arkansas and Missouri. 4. The tertiary distinct on the sea board. 5. The body of sandstone and trap, commencing in New Hampshire, and extending with interruptions into South Carolina. The richest metalliferous district within the territory of the United States, is in the Territory of Wisconsin, and the states of Iowa, Illinois, and Missouri, in all of which are immense quantities of lead ore, imbedded in an ancient secondary limestone. The iron Mountain in Missouri, 300 feet high, and two miles in circumference, is a mass of the secular oxide of iron.

GEOLOGY OF NORTH CAROLINA.

61. *Tertiary Strata.* An obvious and striking feature in the geology of North Carolina, is, the division of the state by a line running in a north-easterly and south-westerly direction, into two parts, of nearly equal extent, but differing widely from each other, in composition, structure, soil, and vegetation. One is a region of fixed rocks, without organic remains, and covered its natural state, with forests of oak, hickory, and other trees, having deciduous leaves ; the other made up of beds of clay and sand, with immense quantities of shells imbedded in them, and the favorite habitat of the long leaved pine. From the first settlement of the country, till within a few years, the received opinion has been, that the low-country as well of North Carolina as of the other Atlantic states, has been gradually thrown up by the waves, and gained from the sea. This view of its origin is proved to be untenable by different facts and agreements.

1. By its elevation above the bed of the ocean. The surveys that were instituted with reference to the construction of the Wilmington rail road, show an elevation of the general surface of Duplin County, of between one hundred, and two hundred feet, above the height of mean tide at Wilmington. But Duplin is one of the lower counties. The court house is not more than 35 miles in a direct line from the sea, whilst it is upwards of 60 miles from the upper limit of the sand ; and throughout the latter distance, the ground constantly rises, as is proved by the fall of the streams, which is also more rapid and considerable, as we approach their sources. The general elevation of the upper border

of the sand, cannot be estimated at less then from three, to four, hundred feet above the level of the sea. From Carthage in Moore County, there is sand uninterruptedly to the coast, and although there has been no accurate measurement of its altitude, data for an approximate estimate are furnished, by what is known of the fall of our rivers in the lower parts of their courses, the estimates by Fulton of the fall in the Cape Fear, between Fayetteville and Haywood, at the mouth of Deep River, the amount of fall in Deep River for 20 miles above Haywood, and the elevation of Carthage above the bed of that stream. Carthage cannot be less than 400, and is probaly 500 feet, above the level of the ocean. It can hardly be necessary to remark, that no amount of clay or sand, and much less a quantity sufficient to form the soil of whole counties, can have been carried by the waves to these heights.

2. By the constitution and structure of the strata in question. They are composed of layers of clay and sand, superimposed one upon another, in a position approaching the horizontal. The clay is foliated, often in leaves of extreme thinness, and fineness, and sometimes with a thin layer of sand interposed, indicating that they were deposited from turbid water, that was tranquil, if not at the surface, at least at the depths where the deposition took place. Their appearance is such as could not have been produced by that tumultuous action of the waves, by which it is supposed that banks of clay and sand may have been thrown up.

3. By the condition of the shells, and other organic remains. They are in a state of perfect preservation, so far at least as their forms are concerned. The original cohesion of the particles composing them, has been partially lost, so that they are easily broken, but they exhibit the markings peculiar to each, the furrows, and processes, by which the different species are distinguished, as perfectly, as when the animal was still living. Shells that are tossed by the waves upon the beach are soon worn smooth, and if not ground down to a fine powder, lose most of their distinctive characters. They also become mixed, irregularly, and in every variety of position, with one another, and with the clay and sand, in which they are imbedded. But the shells of the low country evidently occupy the original places in which the animals lived and died. The different kinds, if not confined to a particular bed or part of a bed, are more numerous at particular points, and with such mixture only of the species, as obtains amongst the living races of the present ocean.

The low country was therefore once the bed of the sea, how has it become dry land? The appearances can be accounted for only upon the supposition, that it has like other parts of the existing continents, been raised above the level of the ocean, by a force exerted, and probably more than once exerted, from beneath.

It is evident on examination, that the sand, and clay, once covered the country more extensively than they do now; that the fixed rocks were originally hidden by them quite up to the highest limit of the sand, that it was all sand and clay as far as a line extending from the western part of Warren, through Franklin, the south-eastern part of Wake, the northern part of Cumberland, a corner of Chatham, the centre of Moore, the south-eastern part of Montgomery, northern part of Richmond, and eastern of Anson. This was, at least for some time, the line of the sea beach, but after the low country had emerged from the waves, by the combined agency of rain water, rushing into the streams, and of the streams themselves, acting upon their banks and beds, the original coating of clay and sand was swept off, and transported to some point lower down. The result was, the formation of a broad belt of unequal width, but generally from 30 to 40 miles across, having sand especially, and some clay—the strata of the low country, and long leaved pine, on the high grounds, and stiff land of greater fertility, fixed rocks, and woods of oak and short leaved pine, in the neighbourhood of the creeks and rivers. We find therefore, granite, slate, and other rocks, sparingly distributed, and near the water courses in the interior of the sand. The small streams rise in the sand hills, and disclose the subjacent rocks only in the lower part of their courses. This is true for example of Upper and Lower Little Rivers in Cumberland, Drowning Creek in Moore, and Hitchcock's, Solomon's, and Marks' Creeks, in Richmond. In descending the country from Raleigh towards Newbern, we strike the sand at the distance of 5 or 6 miles from the city, and have entered fully upon it at the distance of ten miles, but the subjacent rock rises to the surface many miles below: at three points at least around Waynesboro', viz: at Micajah Coxe's on the Raleigh road, on the opposite side of the Neuse a mile or two east of Falling Creek, and at the distance of seven miles on the road to Stantonsburg; so that Waynesboro', though there are no fixed rocks immediately at that place, may be taken as a centre for the lowest limit of fixed rocks on the Neuse. From the Virginia line to Waynesboro', this limit as very near to the route of the rail road; at Halifax, on the Roanoke, the Falls, on Tar River; and 6 miles above Stantonsburgh on the Cotentney. It is a little below Averysboro' on the Cape Fear, near the southern limit of Moore on Drowning Creek, and a little below the South Carolina line on the Pedee. Loose slate rocks are so abundant near the Cape Fear, opposite to Fayetteville, that the existence of a body of them very near to, if not at, the surface, may be strongly suspected, and a discovery of them may hereafter carry the line farther down.

This wide belt is to the geologist the least interesting part of the state. The clay and sand contains, with a very few unimportant exceptions, no organic remains, or imbedded minerals, whilst they cover the older rocks, and render it impossible to observe and study them. What those rocks are, will be stated hereafter. It affords an excellent material for the manufacture of bricks, and coarse pottery, and sand for mortar. There is also on the edge of Tossnot swamp, in Nash, a bed of bog iron ore in this formation. It is generally about five feet beneath the surface, 18 inches thick, and with lumps, or nodular masses, of the same, above. Iron of an indifferent quality was manufactured from it at a forge on the Big Swamp, in 1814-15, and a part of 1816, when the forge was burnt. The quantity of the ore is not such as to warrant the expectation that the enterprize will be renewed.

Below the limits of the fixed rocks, the same associations and alternations of clay and sand are continued, with the addition, either there, or at no great distance below, of marine organic remians. The upper limit of these, is at Murfreesboro' on the Meherrin, Scotland Neck on Roanoke, near Enfield on Fishing Creek, a little below the Falls on Tar River, at Bass's Ferry (a small quantity) on the Neuse and 12 miles above Elizabeth on the Cape Fear. None have been observed within the limits of the state, on Lumber River. *They occur at intervals from the points just named to the ocean.*

Maclure, in a sketch or outline of the geology of the United States, prepared thirty years ago, represents as one *alluvial* formation, a tract commencing at the eastern extremity of Long Island, and extending through the Middle and Southern Atlantic States, embracing the whole of the south-eastern half of North Carolina that is now the subject of remark. But it has been ascertained that different and distant parts of this district, are unlike each other, in age and character. So much of it as lies within the limits of the state of New Jersey, isproved by the imbedded fossils, to be contemporaneous with the cretaceous system of Europe. There are only a few small patches of tertiary in that state. In Maryland the tertiary formations come in in great force, occupying both sides of the Chesapeake bay, and passing through Virginia, are represented as attaining their greatest width in North Carolinia, and to be succeeded by secondary formations in the low-country of South Carolina. But the tertiary of North Carolina, is different from that of the states lying north-east of it, exhibiting a much larger proportion of *recent* shells—species of which the animal is still living on the coast. The proportion of living species in the deposits of Maryland and Virginia, is about 20, whilst in those of North Carolina, it rises as high as 50 or 60 per cent.*

* For these facts, and of course for the conclusions drawn from them, the geologist is compelled to acknowledge himself indebted to the Conchologists, and to Mr. T. A. Conrad of Philadelphia, more largely than to any other individual. Two boxes of shells have been forwarded by the writer for examination by him, from the valley of the Cape Fear; one from Walker's Bluff, in Bladen, and the other from the natural well in Duplin, from which, in part, the inferences just stated were drawn. If it be enquired why greater activity has not been displayed in collecting and forwarding the materials for determining the geological era of a large portion of the state, it may be replied, that the University is at a distance of between 70 and 80 miles in a straight line, from the nearest fossil shell.

The applications and uses of shell marl as a fertilizer of the soil are well known; but some caution is necessary in drawing inferences from the facts stated in the various agricultural papers that have been published in regard to its effects. It is essential to its usefulness, that the shells be in a state of decay, so as readily to fall to pieces, and mingle in the condition of a fine powder with the soil, and so far as their value as a fertilizing agent is concerned, it is unfortunate, that most of the shells of North Carolina belong to the Pliocene, rather than the Eocene, or Miocene eras. In many cases the original cohesion of their particles is scarcely impaired, and they are comparatively worthless. Centuries may elapse, before they shall be brought to resemble the older marls of the present day.*

The comparative newness of the tertiary strata of North Carolina, the much greater proportion of recent or living species found in them, indicates, that an elevating force has been exerted beneath the eastern part of this state, at a later date than on any other part of the coast. Such Pliocene beds as are still reposing beneath the waters of the ocean, off the shores of the states north and south of us, have here, been raised above the surface, and are cultivated soil. The centre of the disturbance appears to have been somewhere amongst the lower waters of the Neuse and Tar. On looking at a map of the United States, it will be seen that North Carolina projects pretty far beyond the general range of the coast. The capes and shoals that render a voyage from New York to Charleston, so long and dangerous, may be regarded as one of the results of these later geological changes.

When however the upheaving of the south-eastern counties, and their elevation above the waters of the ocean, are spoken of as recent events, it is to be understood that they are such, only in reference to other changes in the crust and surface of the earth. Since their occurrence, whole races of animals have perished and disappeared, and new ones been created to supply their places, some new species of vegetables have been called into being, and time enough has elapsed, to allow of the dissemination of others from their original seats, so uniformly, over the new contiguous surface, that no difference is discoverable between the old and new habitats, in regard to either the number, or the variety, of the individuals that occupy the soil. The pines are as widely and as

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* To the Conchologist, the very circumstance which deprives them of value in the estimation of the farmer, gives them additional interest and beauty. The finest collection I ever saw, was one made by my friend and former pupil, Richard Evans, Esq., of Greenville, in Pitt County, whilst raising marl from the bank of the Tar, to be applied to the soil, and of which I have not heard that any essential benefits were derived from it. Upon the students of the University who shall hereafter be settled in the region of these interesting remains, the duty may be earnestly enjoined of lending their aid to these investigations. A box of shells carefully selected, well packed, and forwarded, will be a valuable contribution to the science of Geology.

densely distributed over the Pliocene formations of North Carolina, as over the secondary, or Eocene of South Carolina or Virginia. The Elephant and Mammoth, and apparently no inconsiderable menageries of other animals, which either were pastured in the upper counties, and floated down the rivers after death, or more probably, lived and died, near where their bones were found, have disappeared, the one from the western continent, the other from the earth.

Several teeth and other bones of the Mastodon or Mammoth were found 25 years since, during the excavation of the Clubfoot and Harlow canal, some of which are now in the cabinet of the University. We have also the grinder of an Elephant, found in the marl pits of the late Lucas Benners, Esq., 16 miles below Newbern, and other teeth not yet determined. The same pits afforded also, what were supposed by Mr. Croom to be fragments of the horns, hoof, and grinders, of a fossil elk.

The only metallic substances that have been found within the limits of these deposits, are some of the ores of iron ; the bisulphuret, hydrated oxide, and sulphate, or copperas. The first, occurs imbedded in a tenacious blue clay, and though well characterized when taken from the earth, is changed by exposure to the air, and converted by the absorption of oxygen, into the sulphate. In the bank of the Neuse at Waynesboro', is a mass of small branches of trees, that have been metallized by the substitution of this ore of iron, for the original woody fibre. Lignite,—wood that has been changed into coal, is common.

62. The soil of the tertiary region is of very unequal fertility, unknown causes having produced an accumulation of sand on some points, and of clay, or of that mixture of sand, clay and limestone that forms good land, on others. The best body of land belonging properly to this formation, is undoubtedly on the northern side of the Albemarle Sound,—the incunabula gentis, or spot on which the first permanent settlements in North Carolina were made. What the relative ages are, of the belt of mixed character, having fixed rocks in the beds of the streams, and sand and clay or the high grounds, and of these strata, that are certainly tertiary ; whether they were produced by the same causes, or by different causes, we have no means of determining.

Secondary Strata. A formation of a different character, and as is proved by the shells imbedded in it, of much greater age, contemporaneous with the marls of New-Jersey, and the cretaceous system of Europe, underlies the tertiary, in the southern part of the state, and crops out at intervals, from the eastern part of Jones County, to the Cape Fear. It is well exhibited at Wilmington, with the shells of the tertiary reposing directly upon it. Where it presents itself at the surface, the soil is generally characterized by a much higher degree of fertility. The greater proportion of good land in Jones, depends upon the fact that this formation is largely developed there. The rich lands of Onslow, and of Rocky Point, in New-Hanover, owe their excellence to the same cause. It is not merely by affording lime to the soil, though the effect of this must be considerable, but also by presenting at the surface a mixture of the other earths, that independently of this, is of a very different kind, that it owes its superior productiveness. It may not improbably be ascertained hereafter, that this formation has a more extensive range through Greene, Duplin, and Sampson, than has hitherto been supposed. In the two latter counties especially, as on the Five Runs, and Goshen Swamp, the whole aspect of the country, and the characters of the soil, are different from what is observed in those parts that are unquestionably tertiary.

Where the shells of this formation were imbedded in siliceous sand, they have been dissolved in the course of ages, by the water charged with a small quantity of carbonic acid, derived from the atmosphere, that has flowed over them, and the calcareous matter has descended until it met with the silica, when it has been arrested, and has entered into that imperfect combination with that substance, which constitutes mortar. The result is, a pretty firm rock, hard enough to give fire with steel, and full of cavities, *where shells have been*, an aggregate, not of shells, but of casts of shells. This is quarried and cut into mill-stones, most of which are small, and turned by hand, but some, of the size employed where there is a command of water power. They answer tolerably well, but are deficient in hardness.

When there is little or no sand, we have at some points a simple accumulation of shells, forming a good limestone, sufficiently pure for all the common purposes of building, and of which it might be expected that it would supply a large extent of country with quicklime. Such is that nine miles below Waynesboro', in the north-west corner of Jones, in the northern part of Onslow, at Wilmington, and on the N. W. branch of the Cape Fear, to the distance of forty miles above. But this enterprize has been already so often, earnestly, but ineffectually, recommended that it can apparently answer no good purpose to point it out again, as a field of industry, that promises to reward amply whoever shall have the spirit to enter in and cultivate it.

Of the Middle and Western Counties. The north-western half of the state, is composed altogether of rocks that at an early period in the earth's history were brought into the positions they now occupy; and of the soil that has been formed upon them, by the decay and disintegration of rocks of the same kind. There is no stratum of foreign matter that has been brought in from abroad, in any part of this region, that which has been caused by rain water rushing down the sides of the hills, and the beds of the streams, alone excepted. The evidence of this is furnished by the facts, that the gravel is all angular and sharp, and that the characters of the soil, constantly vary, with those of the subjacent rock. A very few appearances there are that are difficult to account for, one for example on the eastern side of the Yadkin, near the road leading from Lexington to Salisbury ; but the person who shall examine the country extensively, will be satisfied of the truth of the proposition here stated. In treating farther of the geology of North Carolina we have to notice,

1. Two bodies or formations of sandstone.
2. Three bodies of transition slate rocks.
3. Five bodies of primitive rocks.

Sandstones. A formation of sandstone with trap rocks associated, has been mentioned, as extending from the northern part of Massachusetts, with interruptions, into South Carolina (section 21.) Its range and extent in North Carolina will be seen by a reference to the map. Commencing in Granville 3 or 4 miles south-east of Oxford, it passes through Orange and Wake, Chatham and Moore, Montgomery and Richmond, and Anson ; but through some part of Moore, Montgomery, and Richmond, it is covered by tertiary sands and clays. It is of course traversed by four of the large rivers of the state, the Tar, Neuse, Cape Fear and Pedee. Its upper boundary crosses Tar River at Robards' Mill, the streams that form the Neuse, three or four miles above their confluence, the Cape Fear and Deep rivers a little above Haywood, Deep River a second time, three or four miles below Evans' bridge, and a third time, above the mouth of Richland creek, and the Pedee a little below the mouth of Rocky River. On the Tar, its width is not more than six or seven miles. Its lower limit on the Neuse, is a little above the mouth of New Light creek in Wake, about the mouth of Buckhorn on the Cape Fear, and above the Grassy islands on the Pedee. From thence it passes by Wadesboro'* into South Carolina, Brown creek running its whole course in this formation. It approaches to within a mile of the University, and has a breadth of between 15 and 16 miles, on the road leading from Chapel Hill to Raleigh, meeting the primitive of Wake, on the south side of Crabtree, at a distance of about half a mile from that stream. It is nowhere much wider, and generally narrower than where this road crosses. It has less elevation than the formations on each side of it, so that as we approach it, we seem to come to the edge of a broad valley. From the hill on which the University stands, the prospect is extensive towards the east, and south-east, but limited in the opposite direction. Its upper surface may be about 400 feet above the sea, and though everywhere gently undulating, it nowhere rises into hills of any considerable height. Throughout its whole extent, there is probably no one, that is more than 200 or 250 feet above the general level.

The principal constituent of this formation is a fine-grained, greyish, or reddish sandstone, whose particles are cemented by

* There is in Richmond County, between Catleges' and Mountain creeks, a body of the same kind of rocks, but whether connected with the other, or a separate and independent mass has not been ascertained.

a mixture of clay and oxide of iron, and which produces by its decomposition, a soil of very moderate fertility; more favourable to the growth of corn, and cotton, and especially of the sweet potatoe, than to that of wheat. In its native state, it is distinguished from the country west of it, by a growth of short-leaved pine. The south-eastern part of Orange is known as the piney woods. In some places the relative quantity of the clay and iron is greatly increased, and their results are argillaceous sandstone, or slate clay, decomposing into a very dark, liver-coloured soil, which is also characteristic of this formation. Such lands are liable to wash when brought under cultivation, and the roads through them are execrable in a wet season. These different sandstones, are interspersed, and traversed, by masses and dykes of trap, commonly called iron rocks, some of which are crystalline in their structure, and others a fine homogeneous paste, approaching nearly in its characters to basalt.

The rivers that flow through this body of sandstone, have very little fall in this part of their course; the low grounds as well upon them, as upon the smaller water-courses that are altogether within the limits of this formation, are wide, but inclined to be cold and "crawfishy," and liable to overflow, where the streams break down from the formations next to be noticed into the sandstone, producing a greater elevation of the ground, and a mixture of soils of different kinds, one, two, three, or more very good plantations are formed. The property of Messrs. Bennahan, and Cameron, on the waters of Neuse, of Mrs. Patterson, on New Hope, of Cheek, Barbee, and the Morgans, close by the University, of the vicinity of Haywood, in the Cape Fear, and of the Dunas settlement on the Pedee, are examples. In the latter case, the river exhibits in perfection the disposition to wind which is also characteristic of such as flow through the state under consideration. It would seem that after passing through the sterile region above, and being dashed upon the flinty slates and hornstones of the Narrows, and Great Falls, it testified by long circumvolutions its delight at finding repose in the soft bosom of the sandstone, and amidst the fertile fields that border it on either hand.

Small nodules of *compact* limestone, and masses of a loose texture, have been found in this formation, in the upper part of Wake, in Anson, and elsewhere, and it is to be hoped that bodies of such size, as to meet the demands of the farmer, for the purposes of agriculture, may hereafter be discovered. Pieces of silicified wood are of pretty common occurrence. We have specimens from the eastern part of Orange, and from Richmond. But the most important of the substances that are found imbedded in the sandstone, is unquestionably, coal.

A seam of bituminous coal has been known to exist at the Gulph, on the north side of Deep river in Chatham county, for upwards of sixty years, but after having been opened, and used, for some time, it was abandoned, and altogether neglected till within four or five years past, when it was opened anew, and the coal is now used in preference to charcoal, in the black-smiths' shops in the neighbourhood of the mine. Two or three years since a bed of Anthracite coal was discovered on the lands of Messrs. Farish and Clegg, four miles lower down the river, and within the present year, another has been opened on the lands of George Wilcox, about eight miles above. This last, at the point where it was discovered, is so highly charged with iron pyrites as to be unfit to be employed in working iron, but a little exploration might bring to light coal of a better quality. At the other bed it appears to be good. Through nearly the whole of the northern side of this sandstone formation, in the counties of Chatham, Moore, and Montgomery, a distance of 50 miles, the black shales which appear at the surface render it probable that coal may be discovered, and although in a thinly settled country, that is covered with forests, and remote from water carriage it can have no immediate commercial value, it is pleasant to know that we have resources to which we may turn, when those upon which we have hitherto depended shall fail.

A mineral spring that has some reputation, rises from the strata we are describing in Moore. It is a pretty strong chalybeate. Jackson's, a branch of Downing creek, rises in the sand-hills, but has removed the sand so as to bring the subjacent rock to view, for some distance along its bed, and it is from a crevice in a body of trap rocks that the water flows.

The sandstone is quarried and used in building, for which it is in some places well adapted, grindstones of a tolerable quality are cut from it in Montgomery, Richmond, and Anson ; and in the northern part of Moore, instead of the common fine sand, being composed of quartz pebbles, of considerable size, cemented in in the usual way, it is a valuable material for mill-stones, especially such as are to be employed in grinding corn.

This formation has been represented as a continuation of that which passes through Massachusetts, Connecticut, and the Middle States. The only evidence we have of this relationship or identity, is furnished by a similarity of composition; similar sandstones, are associated in the same way, with similar masses of trap. There are however points of difference. Supposing the formation to be parts of the same, which if not continuous, was throughout the result of the same causes ; the irregularities of surface, the relative proportion of the trap, and the quantity of the associated minerals, appear to diminish with some degree of regularity, from its northern to its southern extremity. In New-England the trap forms long ranges of mountains, some of which are from seven or eight hundred to more than a thousand feet in height ; the most elevated of the trap ridges in New Jersey are not more than 400 feet, but they are many miles in length ; in North Carolina they are greatly reduced in both extent and elevation. Minerals of the zoolite family are abundant in New England, of less frequent occurrence apparently in New-Jersey, and rare, if they occur at all, where the sandstone formation traverses Pennsylvania and Maryland : they have never been found in North Carolina.

Disregarding the short interruption of continuity south of Fredericton in Maryland, Professor Henry D. Rogers in his final report on the geology of New-Jersey, supposing the sandstone and trap of that state to be continuous through the intervening states, to the northern "confines of North Carolina," and remarking that it gradually ascends, and grows narrower, as it advances towards the south, so as to be reduced from a breadth of 30 miles at or near New York, to four miles on James River, refers the whole to an ancient river, having its source in the southern states, and estuary at, or near, New York, by which the materials of the sandstone were formed and deposited in their present beds.

If this theory is correct, the sandstone of North Carolina must be referred to a similar, but different origin, and not regarded as part of the same system of rocks. The absence of organic remains indicates a fluriatile rather than an oceanic deposit, but the great objection to the theory is, that it takes no account of the trap. The trap is imbedded in the sandstone, and traverses it in a thousand different directions. It is not met with elsewhere ; in the slates and granite that lie adjacent to the sandstone. Why should a river be liable throughout its whole extent, in length and breadth, to injections and eruptions of trap, whilst nothing of the kind occurs upon its banks ? A theory which embraces and accounts for, a part only of a mass of associated phenomena, is mischievous as well as unsatisfactory, arresting the spirit of examination and enquiry.

Maclure gave to the formations of New England and the middle states the name of old-red-sandstone : Professor Hitchcock regards them as belonging to the new-red-sandstone ; Professor Rogers disliking this precision of nomenclature, and supposing them to be later than the carboniferous rocks, and earlier than the green-sand, denominates them "*the middle secondary series.*" From a general similarity in its aspect, the soil formed by its decomposition, and the character of the rocks associated with it, I cannot but regard the sandstone of North Carolina as the result, if not of the same, at least of similar causes, if not of the same, not of a very different age. But I have no theory to offer in regard to the mode of its formation, or opinion to express respecting its age, other than that it is very old.

Another sandstone formation, with associated masses of trap rocks, beds of black slate, slate clay, anthracite coal, silicified wood, and limestone, enters North Carolina from Virginia, and extends through Rockingham and Stokes counties, along the course of Dan river, and the Town Fork, to Germanton. Its greatest breadth is six miles. The soil resembles that produced by the decomposition of the larger body of sandstone just described, but has greater fertility. Two seams of coal have been observed in it, both on the North bank of the river, one in Rockingham, about four miles above Leaksville ; and the other in Stokes, opposite to the mouth of the Town Fork.

64. *Of the Transition and Slate Rocks.*—These occupy a large space in North Carolina. The principal body of them traverses the State in a north-easterly and south-westerly direction, immediately west of the great sandstone formation, occupying a breadth of about 30 miles. From the South Carolina line, to a point nearly east from Pittsboro', in Chatham county, the slate is in immediate contact with the sandstone ; also passing under it and appearing on the opposite side, in Anson and Richmond. The sandstone, the more recent of the two, lies in a trough, or depression in the slate. At the point mentioned, a body of granite comes in, and separates the two through a distance of about eighteen miles ; after which they meet again near the ridge that divides the basin of the Cape Fear, from that of the Neuse, and continue to touch, nearly through the basin of the Neuse, to a point in Granville, three or four miles east of the Orange line, from whence, to where Grassy creek crosses the Virginia line, the slate is again bounded by granite on the east. The western boundary of the slate is granite throughout. Commencing near where Five Mile Creek passes the South Carolina line, it runs through Mecklenburg, by the Mouth of Dutch Buffalo, to the north-east corner of Cabarrus, thence by the mouth of Abbott's Creek, to a point nearly east and five or six miles distant from Lexington, thence to the south-east corner of Guilford, thence by Ruffin's Mills to the south-east corner of Caswell, thence east of Roxborough to a point in the Virginia line, a little west of the Person and Granville line. This formation includes of course, the western part of Granville, the eastern part of Person, the central part of Orange, more than half of Chatham, nearly the whole of Randolph, the whole of Montgomery, (what is sandstone excepted,) the whole of Stanley, the south-eastern corner of Davidson and Rowan, the north-western part of Anson, and south-western of Mecklenburg. This body of slates forms a coating, and probably not a very thick one, upon a recent, imperfectly crystalline, granite rock, on which it reposes. But the upper surface of the subjacent rock having been irregular, the granite at some points penetrates through the slates, and appears on the surface. The slates also send off tongues, or promontories beyond the lines just designated as their boundaries, and as no good could come of a minute examination of all these irregularities, they have in many cases been neglected. Nor is the passage from granite to slate, sudden and well defined, but through intermediate beds that are neither slate, nor granite, nor any other rock that has a name in the books. These anomalous masses also occupy sometimes a considerable space at the surface.

This formation is of course composed like the rest of the crust of the globe, of the four earths, silica, alumina, lime and magnesia ; but the quantity of lime entering into it is small. The most common and abundant constituent, is a compound of silica and alumina ; simple argillite, or clay slate. This prevails especially near its two extremities ; in Granville, Person, Anson, Mecklenburg and Stanley. In these we find argillite almost to the exclusion of every other mineral. The slate undergoes decomposition very slowly, and has to this day covered itself with a thin coating only, of earth. It furnishes therefore the most decisive evidence of the manner in which the soil of the whole upper country has been formed. When an attempt is made to dig a well, the work advances rapidly at first, but at the depth of three or four feet, and frequently much sooner, a slaty structure begins to develope itself in the earth that is thrown out, the spade is exchanged for a mattock, and long before water is reached, the excavation has to be carried on in a mass of rock, requiring the constant use of gunpowder to shiver it to pieces. Rain water will of course penetrate with difficulty, and in small quantities, into a country so constituted ; the larger part of that which falls, will pass off immediately into the creeks and rivers, springs will neither be numerous nor copious, and in a season of long drought, the slate country suffers more severely than any other. The soil is never fertile, though in a summer when rain falls frequently, tolerable crops are obtained.

In the counties of Montgomery, and Stanley, (and the separation of the original county of Montgomery into these two, may be numbered among the grossest follies of recent legislation,) but especially in the former, the simple and pure argillite gives place to a triple compound of silica, alumina, and magnesia, of which, a range of rugged, but not high nor fertile mountains, passing through the centre of the county, and amongst, and partly on which Lawrenceville stands, are composed. The clay slate appears to occupy a lower level, and to be found especially around the bases of the highlands, as on Clarke's creek, and the Uwhare in Montgomery. In other places both the alumina and magnesia disappear, and we have beds of hornstone, flinty slate, and jasper, such as those crossing the Yadkin at the Narrows, and Great Falls, over which the water has poured for ages, and may continue to pour for ages to come, without producing any other effect than that of giving an imperfect polish to their surfaces. Intermingled with all these, and interstratified with them, are other beds, sometimes massive, and sometimes exhibiting like the rest a slaty structure, constituted of water-worn, siliceous, and other pebbles, united by a cement of silica, forming a rock of great solidity, proving that this formation is not co-eval with the existence of the earth, but made up of the fragments and ruins of older rocks. These conglomerates contain particles of gold imbedded along with the pebbles. The Beaver Dam and Parker's surface mines, are amongst rocks of this character, so also is Reid's where gold was first discovered in North Carolina, and the largest mass found. In some places there is soap stone. In the southern part of Person, in Orange, Chatham, Randolph, and Davidson, there are interspersed amongst the slates, larger patches of granite, or of those rocks, by which a passage is made from slate to granite, these last often coloured green by epidote, and there results a much higher degree of fertility in the soil than where the pure argillite prevails. A fine grained triple compound of silica, alumina, and magnesia found in Orange six miles west of the University, in Chatham and elsewhere is an excellent oil-stone.

Until within five years, the ores of but two metals, (iron and gold) were known to exist in any quantity within the limits of this formation. The argillite often contains imbedded, a quantity of the bi-sulphuret of iron ; Iron Pyrites. If a rock of this kind be roasted so as to expel a part of the sulphur, and acidify a part, and then exposed to the weather, copperas and alum will gradually be formed in it. But that this manufacture may be prosecuted profitably, it is necessary that the materials should be abundant, and they have nowhere been met with in North Carolina, in such quantity, as to justify a person in embarking in this enterprize. Traversing the argillite, are veins of quartz, (white flint,) containing imbedded, small masses of the specular oxid of iron. This is a good ore ; the same that in the Island of Elba has been explored for centuries, but the quantity in any one locality is inconsiderable—such as to furnish specimens to the mineralogist, but not materials for the manufacture of iron. The only important ore bed, of the slate, is on the waters of Tick creek in Chatham. It was from this that the furnace built at the Gulph, on Deep river, before the Revolution, was supplied. Gold appears to be sparingly distributed through the whole body of the slate. But one *vein* of gold of any value has been opened in it ; Barringer's in the north-west corner of Stanley. The great vein of Davidson county, in which lead, silver, copper and zinc, but especially the two former, are associated in such quantities, is near the northern border of this formation. The prevailing rock around the mine is pure argillite, and the soil produced by its decomposition very poor. In the spring of 1838, the owner (Byerly,) of a small tract, was led to examine a spot at the top of a hill, or rising ground of very gentle elevation, in the hope of finding gold. He found the carbonate of lead and then sold his possessions. Mr. King, who became the purchaser, sunk a shaft and fell in with the ores of the other metals during the summer of the same year, and in the following winter, the Washington Mining Company was incorporated. The discovery of this mine is an event of great interest, from the additional evidence furnished by it that the central counties of North Carolina are one of the rich mining districts of the world, where farther developments of mineral wealth may be confidently expected ; as also, that where there are no remarkable indications at the surface, there may be immense bodies of ore below. The Conrad hill, five miles east of the lead and silver mine, rich in gold and affording some copper, belongs rather to the recent primitive, presently to be noticed.

For the time when this vast body of slate rocks was formed, we must go back to the earliest ages of the world ; if not to the time when the present ocean hung as an atmosphere of vapor around a glowing mass of rock ; to another inconceivably ancient, when the whole was still too hot to be the abode of organized beings. Respecting the manner in which the materials of particular strata were produced during such a condition of things, it is useless to speculate.

The slate of the western part of Anson, passing under the sandstone, reappears in the southern part of the county, on the waters of Thompson's creek, and extending under the sand of the tertiary, forms the rapids in the Pedee just above the South Carolina line. It is also in the bed of Mark's creek in Richmond, and in the Northern part of the county, on Mountain creek, after having passed under the sandstone, near the Grassy Islands.

A formation having so intimate a resemblance to that just described, that it may be conjectured not merely to be of the same age, but to have been produced by the same causes, traverses the counties of Wayne, Nash, and Halifax. It is very extensively covered by the sand, especially on the high grounds, but has been laid bare along the banks, and in the beds of the creeks and rivers, so that its limits may be assigned with tolerable accuracy. It is on both sides of the Neuse above the Roundabout in Wayne, in the bed of Falling creek, and at Coxe's bridge : its lower limit crosses the Cotentney at some distance above Cobb's Mill, (at, and below the mill, the rocks are granite ;) the Tar near Strickland's bridge, and passing about midway between Nashville and the Falls of Tar, crossing Fishing creek at some distance above Enfield, it reaches the Roanoke between Weldon and Gaston. On the west, the slate approaches very near to Franklin and Wake, but hardly enters those counties. Its width on the old Stage road from Raleigh to Halifax is about 12 miles, but it is much narrower on the Roanoke, and may thin out in that direction, so as not to enter the State of Virginia. The only metals that have been found within the limits of this formation are gold and iron.

There is a third body of transition slate rocks in the western and north-western part of the State, adjacent to Tennessee. At the extreme west, more than half the county of Cherokee is beyond the boundary of the primitive ; which crossing the Tennessee river at a point below Franklin in Macon county, approaches the State line as it advances towards the north-east, and falls in with it in the western part of Yancey, but a few miles from this, a long projection, or tongue, from the formations of the western slates, extends quite across the Alleghanies, to the bank of the Catawba in Burke. Linville river and the North Cove, run their whole course in this formation, which includes also the head waters of North Toe, and John's rivers, and some of the largest branches of the Watauga. Linville mountain, the Grandfather, and several other high ridges and peaks in the neighborhood, belong to the transition. This body of transition rocks was noticed by Maclure, but supposed by him to be an independent formation lying altogether on the eastern side of the mountains. "A similar formation about fifteen miles long, and two or three wide, occurs on the North Fork of Catawba river, running along Linville and John's mountain, near to the Blue Ridge."

It is composed chiefly of sandstone, with some beds of argillite, and a few of limestone, in the North Cove. The soil produced by its decomposition is poor, and the aspect of the country extremely wild and rugged. It is almost without inhabitants, and generally without roads, or improvements of any kind, all the travel between North Carolina and Tennessee, passing north of it through Ashe, or south of it through Rutherford and Buncomb. The violence of the convulsions in which this remarkable feature in the geology of the state originated, is indicated by the whole structure and appearance of the region comprehended within, and lying around it. The highest point in North America, east of the Rocky Mountains, is not more than fifteen miles distant, and instead of the long parallel ridges that compose the Alleghany range farther north, we have isolated masses, ridges directed towards every point of the compass, and the utmost confusion and disorder. Gold has been collected in considerable quantities from the streams of Cherokee county, which has also beds of iron and statuary marble. In the lower part of Buncomb are the Warm Springs, with a temperature of 104°. They rise on the bank, and in the bed, of the French Broad, give out considerable quantities of nitrogen, but contain very little mineral matter of any kind.

65. *Primitive formations of North Carolina.* These of course comprehend all those parts of the state that have not been described as belonging to the more recent beds. They furnish examples of all the principal varieties of rock belonging to this class ; granite, gneiss, mica, chlorite, hornblende, and talcose slate, quartz rock, serpentine, limestone, etc., but are apparently not all of the same age.

1. A vast body of granite rocks traverses the State in a north-easterly and south-westerly direction, including, if not the whole, the primitive part of the counties of Person, Caswell, (except the north-west corner,) Orange, Guilford, Randolph, Davidson, Rowan, Cabarrus, and Mecklenburg, also some of Lincoln, Iredell, Davie, Stokes and Rockingham. Within these limits there is no well defined gneiss, mica, or other primitive slate, serpentine, or limestone. Mica is rare, and in its stead there is chlorite or hornblende, but even these are not in general well characterized. There are very few imbedded crystals. The whole mass of rock, with a structure more or less of granitic, has an uncrystalline earthy

aspect, indicating a recent origin. It decomposes into a good soil. The primitive tract on which the University stands, and the central and northern part of Granville, have the same characteristics In this newer primitive, are nearly all the valuable *vein* mines of gold, and all the veins of copper, that have been wrought within the limits of the State of North Carolina ; not in immediate contact with the granite, but in beds of ill defined chlorite or clay slate, that are associated with or rest upon it. It may be conjectured that a galvanic influence, excited by the contact of large masses of granite and slate, in the early ages of the earth, determined the separation from the whole body of each, of the gold, silver, copper, lead and other metals, they severally contained, and their collection, near the common boundary, into the mineral repositories or veins, from which they are now extracted. Very great quantities of iron pyrites, are raised from the mines of both copper and gold.

2. West of the formation just noticed, are the most ancient primitive rocks ; on the upper waters of the Dan the Yakkin, the Catawba, the French Broad, and their tributary streams. These are the counties of the mineralogist, where the various rare and beautiful, but worthless, crystalline forms, which it is his delight to discover, describe, and arrange in his cabinet, may be sought with some reasonable expectations of finding them. There is a great variety of granites in this region The ternary compound of quartz, feldspar, and mica is the most common, but with endless diversities, depending upon the proportion, colour, size of the grains, and other characters, of the constituent minerals. The gneiss and slates of different localities are less unlike, though they too are sometimes very dissimilar. All these are so interstratified, so alternate with, and are imbedded in each other, that an attempt to assign the limits of each, would be alike difficult and useless.

The most important and valuable mineral furnished by the ancient primitive rocks of North Carolina, is iron ore, of which there are three principal localities. 1. That of Stokes and Surrey, near the dividing line of which counties, there is a series of beds, extending in a north-easterly and south-esterly direction, from the Virginia line, to the Yadkin river. There are also some beds on the southern side of the river. The ore is nowhere very abundant, though in sufficient quantity to supply the demand of a few forges. It consists of a mixture of the brown and black oxides, disseminated under the form of grains, small crystals, and amorphous masses, through mica slate and gneiss rocks, forming the variety called by the workmen shot ore. The proportion of the ore to the including rock, is sometimes so small as to render washing for the purpose of removing a part at least of the earthy matter, necessary, before it can be smelted. But this can be effected by a process so cheap as to render the operation profitable, only when the rock has been softened by a partial decomposition. The iron made from this ore is of a good quality. 2. That of Lincoln, where the ore is of the same kind, abundant, and good, and the quantity of the iron manufactured much greater. There are in Lincoln four furnaces, which are in blast during more than half the year, and about twelve forges. The Lincoln iron is also good, but is said to possess the quality of toughness, in greater perfection than that of hardness. Though some iron has been made in Wilkes, Burke, and Rutherford, the ore beds of those counties are of less importance. 3. The third principal body of iron ore is on the other side of the ridge, in the counties of Ashe and Yancey—in the extreme north-western part of the latter county. Much of it is in rocks containing hornblende as one of their ingredients, and the metal obtained from it is excellent, being both tough and hard, and eminently fitted therefore for most of the uses to which iron is applied.

Gold has been found in small quantities in most of the western counties, but in the most ancient primitive, it is collected from surface mines. Minute veins and small pockets holding grains of the precious metal imbedded, are distributed through these rocks, and as disintegration has proceeded, the gold has been carried by water down the declivities, into the beds of the neighbouring streams. The counties of Rutherford and Burke, have hitherto been found richer in these deposits than any other.

Limestone has been discovered at three points in the primitive rocks in Stokes county ; at one on the bank of the Yadkin, three miles below Rockford in Surrey, and at several places in the south-eastern part of Buncomb and Henderson. Small nodules and masses also have been found about Lincolnton, encouraging a farther search, in the hope that larger bodies may be discovered. The limestone of King's Mountain is in a small tract of later primitive, bearing an intimate resemblance to the country around Charlotte, and like that rich in veins of gold.

Plumbago, or black lead, is found at several places in Stokes, Surrey, Wilkes, Burke. Iredell, and Lincoln. Sometimes it is in considerable masses, sometimes in smaller masses or grains, distributed through the rocks, and again it is diffused through the whole of a bed of mica slate, communicating to it, its own dark colour. Beds of serpentine are common beyond the ridge. Besides asbestus, chalcedony, and other earthy minerals, some of them contain an immense number of small octahedral crystals of the magnetic oxide of iron, and one on the south fork of Toe river, is highly charged with irregular grains of the chromate of iron. There is a whole hill of amianthus in the northern part of Yancey.

Springs whose waters hold dissolved a small amount of mineral matter, chalybeates and others, are not uncommon ; but there are few which are so strongly impregnated as to be worthy of particular notice. In some cases, rising near the bottom of a declivity, they ooze through a mass of vegetable and some animal matter that has been washed down from above, and the water is employed as a remedy for diseases, because it has an offensive smell. In general the water of this primitive region is very pure and good. That of Deaver's spring, four miles from Ashville, contains a considerable quantity of sulphuretted hydrogen.

3. There is a body of very beautiful porphyritic granite in the counties of Anson and Richmond, bearing no resemblance to any that is met with elsewhere in the state, a few masses in the bed of the Cotentney above Stantonsburg excepted. It is on both sides of the Pedee below old Mount Pleasant, the former county-seat of Anson, and but for the circumstance of its being unhealthy, one of the loveliest spots in North Carolina. It forms an excellent soil by its decomposition; millstones of a tolerable quality are cut from it in Richmond; it is not known to contain any imbedded minerals.

4. The small field of granite on which the University stands has been sufficiently noticed. East of the red-sandstone, in the counties of Cumberland, Wake, Granville, Warren, Franklin, Nash, Johnston, Halifax, and Northampton, is another body of ancient primitive rocks, largely covered by the sand. Amongst these, granite prevails more extensively than any other, and where the tertiary sand is absent, there is a fertile soil. The western and northern part of Wake county, where magnesian slates and quartz rocks come in, is probably inferior to any other in this whole area, the tertiary sand always excepted. The imbedded minerals are few. Nodules and masses of Plumbago are found at intervals, from a point north-west of Raleigh, to near the Cumberland line. That of the principal bed, on the waters of Crab-tree, is pure and good, and has been explored to some extent, and with profit, for many years. Above the falls of the Neuse is a large body of serpentine and other magnesian rocks. Much of the serpentine is too highly charged with small grains of oxide of iron, to admit of its being cut and polished as an ornamental stone, but in so large a mass, it may be expected that a diligent search would discover such as possesses every desirable quality, of solidity, strength, and beauty. With this notice of the lowest, and probably not the least ancient of our rock formations, we close this outline of the Geology of North Carolina.

THE END.