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BASALTIC FORMATIONS ON THE COLUMBIA RIVER.

THE

ELEMENTS OF GEOLOGY,

FOR POPULAR USE;

CONTAINING

A DESCRIPTION OF THE GEOLOGICAL FORMATIONS AND MINERAL RESOURCES

OF THE

UNITED STATES.

BY

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TO

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PROFESSOR OF CHEMISTRY, MINERALOGY, AND GEOLOGY,
IN YALE COLLEGE:

WHOSE ENLIGHTENED ZEAL AND PERSEVERING
LABOURS

HAVE LARGELY CONTRIBUTED

TO DEVELOPE THE NATURAL RESOURCES OF
OUR COUNTRY;

TO ELEVATE THE CHARACTER,

AMELIORATE THE CONDITION,

AND

INCREASE THE HAPPINESS,

OF THE

AMERICAN PEOPLE,

THESE PAGES

ARE MOST RESPECTFULLY INSCRIBED.

PREFACE.

No department of the natural sciences possesses greater interest, or leads to more important practical results, than that of Geology. Of late years it has attracted almost universal attention, not only from the fascinating wonders it discloses, but also from its obvious and extensive application to the economical purposes of life. Of such importance has it been regarded, that many of our state legislatures, as well as the general government, have authorized geological surveys to be made, in order that the natural resources of the country may be brought to light and fully developed. Every American must feel a degree of pride in reflecting that, in a short period, the geological features and mineral treasures of no country on the globe will be better understood or more justly appreciated than those of our own. Already have these surveys contributed millions in value to the productive industry of the land; and every year their importance is more and more demonstrated and acknowledged.

To the young the study of geology is peculiarly attractive, as the objects of which it treats are addressed to their observing faculties, which at this period are in a constant state of activity. For a long time this science was nearly a sealed book to all except a few philosophers, so wrapped up was it in technical terms, absurd speculations, and fanciful hypotheses. But the age of speculation has passed; facts are now sought after, and everything is brought to the test of utility. The intimate connexion of geology with agriculture, mining, architecture, and engineering, is too obvious to escape the notice of the least observing; and the practical advantages hence resulting will continue to secure to the science the attention of every intelligent citizen.

In preparing this little work, I have endeavoured, as far as possible, to divest the subject of technicalities, and, avoiding theory, to present facts in a familiar and popular way. Beginning with the properties of matter, I have proceeded briefly to describe those chemical laws, which are chiefly concerned in the production of geological phenomena, thus preparing the way for the intelligent understanding of what follows by those who have had no opportunities of becoming acquainted with these branches of science. It has been my aim, by introducing a simple arrangement suited to the present state of our knowledge; by avoiding all hypothetical considerations; and by illustrating important facts by means of plates and woodcuts, to render the science attractive to all classes of readers, and to produce a treatise which might be used with advantage in schools and other seminaries of learning.

In the second part, embracing nearly half of the work, will be found perhaps the fullest description of the geological formations and mineral resources of the United States hitherto published in any systematic treatise. In this part of the volume a method of classifying the subjects of geological research has been adopted, in accordance with the elementary views given in the first part, so as to present a large mass of arranged information in a small compass. The advantages attending this systematic plan are too obvious to need remark.

The reader will perceive that I have extensively consulted the able works of Bakewell, Philips, Lyell, De la Beche, Ure, Conybeare, Buckland, Mantell, Cuvier, &c., of Europe; and the State Geological Reports of Messrs. Hitchcock, Jackson, Beck, Conrad, Featherstonhaugh, Emmons, Hall, Vanuxem, Eights, Eaton, Wm. B. and H. D. Rogers, Ducatel, Hildreth, Briggs, Troost, Mather, Percival, Shepherd, and Houghton; whose labours are shedding a flood of light upon the geological structure and mineral treasures of this country. Besides these, I have had free access to all the scientific periodical journals, and been favoured by Professors Torrey and Francis of this city with numerous important documents, for which I desire to express my grateful acknowledgments. I have also drawn largely upon Mr. Maclure and Professor Silliman, whose names, indeed, ought to stand first on the list of American geologists; for the able "Sketch of the Geology of the United States" by the former, and the "Journal of Science and the Arts" conducted by the latter, have done, perhaps more to diffuse a taste for geological studies among us than all other causes united. It will be seen that, in some instances, I have not hesitated to employ the language of others in the description of facts, where it seemed appropriate; but in the expression of opinions I have carefully guarded against it. Such a work must necessarily, to a great extent, bear the character of a compilation; and whatever claims to originality it may possess, will not fail to be discovered by the intelligent reader.

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PART I.

CHAPTER I.

SCIENCES AUXILIARY TO GEOLOGY.

Definition.—Physical Properties: Extension, Gravity, Impenetrability, Divisibility, Porosity, Indestructibility, Inertia.

Geology is that branch of physical science which treats of the constitution of the earth we inhabit. It not only has for its objects an investigation into the form and external characters of our globe, but also into the nature and relative position of the materials which constitute its external crust, and the manner and order in which these materials have assumed their present position. Geology, therefore, embraces the science of Physical Geography; but, before entering upon this branch of our subject, it will be proper to take a brief survey of those auxiliary sciences, some acquaintance with which is indispensable to a full understanding of what is to follow.

The properties of material substances are of two kinds, physical and chemical; the study of the former comes under that department of science called *Natural Philosophy*, the latter under that of *Chemistry*.

The physical properties are either general or secondary; those are called general which are common to all bodies, while the secondary only belong to a few. Among the first may be enumerated *Extension*, *Gravity*, *Impenetrability*, *Divisibility*, *Mobility*, *Porosity*, *Indestructibility*, and *Inertia*.

Extension is the property of occupying a certain portion of space. This is called the *volume* of a body, and the quantity of matter which it contains is its *mass*. Every substance in nature has length, breadth, and thickness; and the limits of its extension are called *figure* or *shape*. A *vacuum* is a portion of space destitute of matter.

By the *gravity* of a body is meant its tendency to fall towards the earth; and the power by which it is thus drawn is called the *attraction of gravitation*. The force required to separate a body from the surface of the earth is called its *weight*, and this is in proportion to its quantity of matter. Every particle of matter in the universe is under the influence of this principle; by it the moon is drawn towards the earth; while both these, together with all the other planetary bodies, are drawn towards the sun. Solar systems, of which each fixed star, so called, constitutes the centre, are thus bound together; while all of them, there is good reason to believe, revolve around some common centre in the bounds of infinite space.

The velocity of a falling body is accelerated in proportion to the height of its fall, which proves that the force of gravity is greatest at the surface of the earth, from whence it decreases, both upward and downward; so that, at the centre of the earth, a body would be entirely at rest. The ratio of this diminution is as the *square of the distance*, the square of any number being that number multiplied into itself. Thus, if a body on the surface of the earth, which is 4000 miles from its centre, weighs one pound, if it be carried twice this distance from the centre, or 8000 miles, it will weigh but a quarter of a pound; and if carried three times the distance from the centre, it would weigh but one ninth of a pound, or less than two ounces. Now the moon is 60 times as far from the centre of the earth as the centre is from the surface;

therefore, as the square of 60 is 3600, a body will weigh 3600 times less at that distance than upon the surface of the earth: so that a body which weighs a pound here would, at the distance of the moon, be literally lighter than a feather.

In geology we frequently have to speak of the *specific gravity* of bodies, which is the weight of a body compared with the weight of another body of equal bulk; which latter is regarded as the standard of comparison. The standard generally employed is rain or distilled water, a cubic foot of which weighs 1000 avoirdupois ounces. A balloon ascends in the air, because the gas with which it is inflated is *specifically* lighter than the atmosphere in which it floats; and a piece of board* swims on the surface of water, because its specific gravity is less than that of water; in other words, it occupies less space than a body of water of the same bulk. For the same reason, a piece of lead or iron will swim in a vessel filled with quicksilver, while a piece of gold will sink. In the one case, the specific gravity is less, in the other, greater than that of quicksilver. To find, then, the specific gravity of any body, we have only to weigh it in air, which is its *absolute* weight, and then in water, which is its *relative* weight, and then compare the two results. Thus, suppose a stone weighs in air 390 grains; in water, as it will be partly supported, it will weigh less by 80 grains than it did in air: and this difference is precisely the weight of the water displaced by the stone, or a quantity of water equal to the bulk of the mineral. Now we get the specific gravity by

* *Mr. Scoresby* has proved that the most porous, and, therefore, the lightest kinds of woods may, by being sunk deep below the surface of the ocean, acquire a specific gravity so great as to cause them to sink in water like lead. He tried this experiment with deal and other light kinds of wood. This phenomenon is owing to the immense pressure which the wood sustains by the water.

dividing the absolute weight 390, by the difference of its weight 80, in air and water. Thus, 390 divided by 80 is 4.875,* the specific gravity of the mineral.

Impenetrability is that property of matter *by which two bodies cannot at the same time occupy the same space.* This property has been called the mainspring of all mechanical motion, as it affords to the oars of boats, to the wheels of mills, and various kinds of machinery, and the sails of vessels, a resistance in water and air which propels them onward; and without such a property of matter, human genius could be of no avail.

Divisibility.—Matter has been said to be infinitely divisible, but it would be more correct to say that it is divisible to an extreme degree of minuteness. For example, a grain of gold may be so extended by hammering as to cover 50 square inches of surface, and contain two millions of visible points; and the gold which covers the silver wire used in making gold lace, is spread over a surface twelve times as great. A grain of iron, dissolved in nitro-muriatic acid, and mixed with 3137 pints of water, will be diffused through the whole mass; for, by using some chemical test, a portion of iron may be detected in every part of the liquid. This proves that the iron has been divided into more than 24 millions of parts; and if the same quantity were still farther diluted, the diffusion of the iron through the whole mass might be proved, by concentrating any portion of it by evaporation, and employing its appropriate tests. Newton succeeded in determining the thickness of very thin laminæ of transparent substances by observing the colours which they reflect. A soap-bubble is a thin shell of water, and

* A very convenient instrument for ascertaining the specific gravity of bodies is Nicholson's Portable Balance, which may be obtained at any of the shops where philosophical instruments are kept for sale, with directions for its use.

reflects different colours from different parts of its surface. Immediately before the bubble bursts, a black spot may be observed near the top. At this part the thickness has been proved not to exceed the 2,500,000th of an inch. Many insects have transparent wings so thin, that 50,000 of them placed over each other would not form a piece a quarter of an inch in height.

In the organized world we have still more striking examples of the extreme minuteness of matter. The blood which circulates in the arteries and veins of animals is not a uniformly red fluid, but consists of a watery portion called *serum*, containing small red globules. These globules are found to differ in size and shape in different species. Thus, in man, and in all animals that suckle their young, they are round or spherical; in birds and fishes, of an oblong, spheroidal form. In man, these globules are about the 4000th part of an inch in diameter; and it can be shown, that in the small drop of blood which remains suspended from the point of a fine needle, there must be contained more than a million of these globules. Again, animalcules have been discovered whose magnitude is such that a million of them does not exceed the bulk of a grain of sand; and yet, by means of the solar microscope, we find that these creatures, such as are even invisible to the naked eye, are composed of bones, and muscles, and bloodvessels; that they have life and motion, sense and instinct, and, in short, are as curiously organized as animals of a larger size.

We have stated that the *volume* of a body is the quantity of space included within its external surfaces, and that its *mass* is the collection of atoms or particles of which it consists. Now if these atoms are actually in contact, the *volume*, of course, will be completely occupied by the *mass*, so that the greater the density the less will be the *porosity*. But there is reason to believe that this is not the case in any known body. Consequently, all bodies are more or less porous; that is, have interstitial spaces, which are either empty, or filled by some substance of a different nature from the body in question. Volcanic lava is so full of cavities filled with air, that it floats upon water.

There is a mineral called *hydrophane*, which manifests its porosity in a very remarkable manner. It is a silicious stone, and in its ordinary state is semi-transparent. On plunging it, however, into water, and then withdrawing it, we find it to be as translucent as glass. The pores, in this case, which were previously filled with air, are now filled with water, which renders the mineral transparent.

It is common to see water percolating through the sides and roofs of caverns and grottoes, and, being impregnated with calcareous and other earth, form stalactites, hanging like icicles from the roof, and presenting a highly interesting appearance This is owing to the porosity of such rocks. The *nearer* the particles of which a body is composed approach each other, the *harder* is it said to be.

Thus, among minerals, the *diamond*, which is *consolidated carbon*, is the hardest; and *naptha*, or *petroleum*, is one of the softest. We judge of the relative hardness of minerals by the readiness with which they receive impressions by a sharp-pointed body. For example, the sharp edge of a piece of flint will scratch glass, and a diamond will scratch both; quartz scratches feldspar, and topaz scratches quartz; fluor spar scratches calcareous spar, while the latter scratches gypsum; so that this character is of great value in determining the species of any unknown mineral.*

* One of the secondary properties of bodies, which it is proper here to notice, is *elasticity*. It is by the aid of this property that bodies, when relieved from the influence of a compressing force, restore themselves to their former dimensions. All elastic bodies are therefore compressible, though all compressible bodies

By *indestructibility* is meant that, according to the present laws of nature, matter never ceases to exist. It may change its *form*, but it cannot be destroyed. Thus we see water and volatile substances dissipated by heat; wood and coal are consumed in the fire and disappear. But, in such cases, not a particle of matter is annihilated. The body appears, indeed, to have been destroyed, but it has only undergone a change of form; a part has been driven off in vapour, a part in gas, while a still larger portion remains behind in the form of ashes or cinders. This fact, as connected with changes upon the surface of the earth, was known to the ancients, for we read in Ovid* "Nothing perishes in this world; but things merely vary and change their form. To be born means simply that a thing begins to be something different from what it was before; and dying is ceasing to be the same thing. Yet, although nothing retains long the same image, the sum of the whole remains constant." Some of the illustrations which are adduced are as follows: "Solid land has been converted into sea. Sea has been changed into land. Marine-shells lie far distant from the deep, and the anchor has been found on the summit of hills. Valleys have been excavated by running water, and floods have washed down hills into the sea. Marshes have become dry ground. Dry lands have been changed into stagnant pools. During earthquakes, some springs have

are not elastic. Thus the operation of the air-gun depends on the elasticity of the atmospheric air, which is increased in proportion to the pressure. *Mica*, or isinglass, is highly elastic among minerals; and elastic bitumen, or mineral caoutchouc, is still more so. *Talc*, which closely resembles mica, is highly flexible, but not elastic; and slabs of limestone in some parts of Massachusetts possess the same property. Among minerals, steel, or iron combined with carbon, is the most elastic substance known. The other metals possess this property in a much inferior degree.

* Ovid's Metamor., lib. 15.

been closed up, and others have broken out. Rivers have deserted their channels, and have been reborn elsewhere. Islands have become connected with islands, as Leucadia and Sicily. Land has been submerged by earthquakes, and plains have been upreared into hills. There was a time when Etna was not a burning mountain, and the time will come when it will cease to burn."

The last property of matter which we shall notice here is *inertia*. By this we mean that matter is inactive; it has neither the power to move nor to stop its motion; in short, is incapable of spontaneous change. This is equivalent simply to saying, that mere matter is destitute of life; it has no principle of action in itself; and, accordingly, common sense teaches us, if we see an inorganic body in motion, to attribute it to some cause extraneous to itself. If such a body be once put in motion, it must always continue in motion, unless resisted by some external cause; it has no more power to stop than to commence running. Indeed, the same causes which destroy motion in one direction, are capable of producing as much motion in the opposite direction. Thus, if we stop a wheel spinning on its axis by seizing one of its spokes, we find that it requires the same effort as it would have done had the wheel been at rest, to put it in motion in the opposite direction with the same velocity. So, if a carriage drawn by horses be in motion, the same exertion of power in the horses is necessary to stop it, as would be necessary to back it if it were at rest. It follows, therefore, from this reasoning, that a body which can destroy or diminish its own motion, can also put itself in motion from a state of rest. But as this is manifestly impossible, so also is the other. Thus the heavenly bodies continue to roll on in their appointed paths of infinite space with unerring regularity, preserving without diminution all that motion which they first received trom the hand of the Divine Architect. A few practical examples will show the importance of a knowledge of this principle, which, though taught by observation and even by instinct, is, nevertheless, often lost sight of in the daily walks of life.

If a carriage, horse, or boat moving with speed be suddenly stopped, the passengers, riders, or any loose bodies which are carried will be precipitated in the direction of the motion; because, by their inertia, they are disposed to persevere in the motion which they shared in common with that which transported them. So, also, if a passenger leap from a carriage in rapid motion, he will fall in the direction in which the carriage is moving at the moment his feet touched the ground, because his body, on quiting the vehicle, retains, by its inertia, the motion which it had in common with it. In such a case, it would be far safer to leap as far as possible into the air, so that, by the time he strikes the earth, the momentum of the body may have been lost; for the reason a person falls under such circumstances is, that while motion is destroyed by the resistance of the ground to the feet, it is retained in the upper part of the body, so that the same effect is produced as if the feet had been tripped. In starting a train of loaded cars upon a railroad, we see that a considerable amount of power is neccesary to communicate motion; but afterward, very little force comparatively is required, only sufficient to overcome the friction of the rails, which is slight. The same holds true of loaded vehicles drawn by oxen or horses.

There can be no doubt that this property is instinctively taught to the brute creation. For example, in coursing, when the hare is closely pursued by the greyhound, she suddenly doubles, that is, turns back upon her course, at an oblique angle with the direction in which she had been running, while the hound, being much heavier, is unable to resist the tendency of its body to persevere in the rapid motion it had acquired, and is therefore urged many yards before it is able to check its speed and return to the pursuit. In the mean time, the hare is gaining ground, and thus, though much less fleet, often escapes. The fox* also is known to practise the same artifice.

CHAPTER II.

CHEMICAL CONSTITUTION OF THE EARTH'S SURFACE.

Definition.—Four Elements according to the Ancients.—Chief Chemical Elements which enter into the Earth's Crust: Oxygen, Hydrogen, Nitrogen, Carbon, Sulphur, Chlorine, Fluorine, Phosphorus.—Metallic Bases of the Alkalies and Earths: Silica, Alumina, Potassium, Sodium, Magnesium, Calcium.—Imponderable Agents: Heat, Light, Electricity, Galvanism.—Thermometer.—Affinity.—Cohesion.—Illustrations.—Compound Elective Affinity.—Cases.

Chemistry has been defined to be the science of analysis and combination. It leads us to a knowledge of what bodies are composed; teaches us the nature and properties of their several elements, under what circumstances these elements unite, and the result of such union. Of course, a knowledge of this science is essential in ascertaining the nature of the materials which enter into the constitution of our globe, as well as the laws which regulate their combination.

The ancients believed that there were but four elements: fire, water, air, and earth; and, consequently, that all bodies were formed by a union of

* Dr. Lardner.

these four substances. Now, however, it is known that there are more than fifty elements, of which most are metals. By an element is understood a body which has not been decomposed, and is therefore believed to consist of one substance only, although it is possible that it may consist of more.

The principal elements or substances which enter into the composition of the earth's surface are 14 in number, and may be classed in the following order, according to the respective importance of each.

Simple Non-Metallic Substances.

1. Oxygen.	5. Sulphur.
2. Hydrogen.	6. Chlorine.
3. Nitrogen.	7. Fluorine.
4. Carbon.	8. Phosphorus.

Metallic Bases of the Alkalies and Earths.

1. Silicium.	4. Sodium.
2. Aluminium.	5. Magnesium.
3. Potassium.	6. Calcium.

Fourteen simple substances, then, by their various combinations, form by far the largest amount of all the matter, whether gaseous, liquid, or solid, organic or inorganic, which is known to exist on the surface of the earth.

Oxygen is an invisible gas,* heavier than atmo-

* A *gas* is an invisible, transparent, elastic fluid, which remains in an aeriform state, and therefore differs from a *vapour*, which, by cooling, returns to its original liquid or solid form. Thus, water, mercury, sulphur, &c., can be converted into vapour by heat; but they soon resume their solid form upon cooling. In this manner sulphur is sublimed, and collected for use in the arts and in medicine; and it also collects in large quantities on the craters of volcanoes and on the borders of sulphurous springs. When we speak of the *specific gravity* of a gas,

spheric air, and is essential to animal and vegetable life. It is by the absorption of this gas that the dark venous blood assumes a florid red colour in the lungs; and without this change, the functions of the body would soon languish, and death speedily ensue. The quantity of oxygen which enters into the constitution of our globe is enormously great. It forms 20 per cent. of the volume of the atmosphere; a third part, by measure, of the gases composing water; and rocks embrace an immense amount besides. *Silica* has been computed to constitute 45 per cent. of the mineral crust of the earth; and silica consists of 48 parts *silicium* and 51 parts of *oxygen.*

When we consider, then, the vast amount of oxygen contained in the waters of the ocean, in the atmosphere, and in the rocks, we shall perceive that it is one of the most abundant elements which enters into the chemical constitution of the globe.

Hydrogen, sometimes called *inflammable air*, is the

the atmospheric air is understood as the standard of comparison. Gases are produced in immense quantities in the interior of the earth by the influence of internal heat, and there can be no doubt that many earthquakes and volcanic eruptions are caused by the sudden irruption of water upon internal fires. This may be illustrated by the explosion of powder, which is a mixture of charcoal, saltpetre, and sulphur. These substances are suddenly decomposed, and gases formed by a combination of their elements, the production of which causes a violent concussion in the atmosphere productive of sound. It is now ascertained that many of the gases may be reduced, by powerful compression, into liquids; as, for example, carbonic acid gas, which, under the enormous pressure of 36 atmospheres, is first reduced to a state of liquefaction, and then to a solid, while, at the same time, a degree of cold is produced equal to —136 degrees of Fahrenheit. In this form it is perfectly white, like snow, and of a soft and spongy texture. Quicksilver, when brought in contact with it, becomes solid, and can be cut and hammered out like lead. If applied to the skin, it speedily destroys the part, indeed as rapidly as a red-hot iron. We see, then, that one of the gases may exist either in an aeriform state, or in that of a liquid, vapour, snow, or ice.

next most important element in nature. It is derived from two Greek words, signifying "*water*" and "to *form*," because with oxygen it forms water; and, when exhibited, it is generally obtained from the decomposition of water. It is without taste or odour, and is the most inflammable of all substances. When mixed with atmospheric air, it burns with a violent explosion. Hydrogen is 14 times lighter than atmospheric air, and for this reason it is used to inflate balloons. It is obtained for this purpose by mixing together sulphuric acid, iron filings, and water, which results in the decomposition of the latter, and the consequent liberation of the hydrogen.

In order to form a correct idea of the quantity of hydrogen on the globe, we must bear in mind that water consists of two volumes of hydrogen and one of oxygen, and, consequently, so far as water is concerned, the quantity of hydrogen is double that of oxygen. With respect to the waters of the ocean, we must deduct about four per cent. for the amount of salts in solution; but with this allowance, when we reflect that the ocean has an average depth of three miles, and covers three fifths of the surface of the globe, we perceive that there must be a vast amount of hydrogen locked up. To this must be added the immense quantity of water contained in rocks* and in the interior of the earth, which, though chiefly derived from the atmosphere in the form of rain, and filtering through immense

* The following is a statement of the average per centum of water, in all the simple minerals containing it, that usually enter into the composition of rocks:

Sulphate of lime	19.88
Serpentine	12.75
Diallage	8.20
Talc and stealite	4.20
Pyroxene	3.74
Mica	2.65
Quartz	1.62

deposites, and gushing forth to fertilize and beautify the surface of the globe, again to be evaporated and again to fall, constitutes no small item in the aggregate amount.

The amount of hydrogen contained in coal, lignite, and peat, is by no means inconsiderable. Some varieties of coal, as the Cannel and others, contain as much as 21 per cent. of hydrogen; this, combined with carbon, forms the gas used for lighting cities.

In many places, especially where coal and rock-salt are found, hydrogen issues in a constant stream from the earth, as at Bristol, Honeoye, &c.; and many places in the western part of New-York, and a village on Lake Erie, are lighted by this means. The phenomenon of burning springs, of which almost every country, particularly China, furnishes numerous examples, is owing to the same cause.

Nitrogen gas, or *azote*, is chiefly important as constituting 80 per cent. of the atmosphere. It neither supports combustion nor animal life. It abounds in animals and vegetables, being obtained, doubtless, from the atmosphere; some have supposed that it also exists in rocks which contain animal organic remains. Some species of bituminous coal contain 15 per cent. of nitrogen.

Carbon abounds not only in living animal and vegetable substances, but also in fossil vegetables and limestone. It forms the largest proportion of every species of coal, bituminous coal containing from 50 to 75 per cent., and anthracite often as much as 90 per cent. of carbon. Diamond is pure carbon. It also enters into the composition of many of the metallic minerals, as iron, lead, zinc, and copper. De la Beche remarks, that if carbonic acid be composed of equal volumes of the vapour of carbon and oxygen, the volume of the vapour of carbon condensed in the calcareous strata must be very great. Taking the specific gravity of pure limestone at 2.7

and estimating the weight of 100 cubic inches of carbonic acid at 47.377 grains, every cubic yard of pure limestone would contain 17,092 cubic feet of carbonic acid gas. If, then, all the carbon contained in the various rocks were set free over the surface, the quantity would be immense, and animal life immediately destroyed. It is well known that vegetation could not be supported without carbon. All vegetables absorb it, while animals give it off by respiration. Thus a purifying process is constantly going on by means of the vegetable kingdom, without which carbonic acid gas would soon abound to such an extent as to extinguish animal life. This gas is given off in immense quantities from numerous springs and fissures in the earth. M. Bischoff estimates that 219,000,000 pounds of this gas are evolved from the vicinity of the Lake of Larch in one year, equivalent to nearly two billion cubic feet in volume.

Sulphur is a well-known solid, brittle, shining substance, of a bright yellow colour. When subjected to heat, it evaporates, and is condensed upon any cool substance, in the form of a fine powder, called *flowers of sulphur*. Sulphur is most abundantly found in connexion with volcanoes,* from whence it

* M. Von Leonhard, in his Lectures on Geology, remarks, that "out of the crater of Parace, in Columbia, vapours of sulphur rise so copiously, that crusts of sulphur eighteen inches thick are formed; pieces of wood, exposed to the influence of these vapours for several days only, are covered with crystals of sulphur. The rocks which surround the crater of *Alaghez*, the volcano from which flows such immense quantities of lava that they now load the plain of Armenia on the north, are entirely covered with sulphur; the inhabitants in the vicinity gather large quantities of it, and in a very peculiar manner. As the summit is inaccessible, they employ guns, as Dubois relates, and shoot through the covering of sulphur; the pieces then fall down at their feet. The Greek island of Milo is very rich in sulphur. Numberless caves are full of sulphur and alum. When the walls of these caverns, which are covered with crystals of these substances, are illuminated, a most magnificent

is mostly procured as an article of commerce. But it is also disseminated among many other rocks. Combined with iron, it forms a beautiful mineral, called iron pyrites, of a yellow colour, often mistaken by the ignorant for gold. Most of the lead ore is also combined with sulphur, forming a sulphuret. The same is also true of zinc and copper. Gypsum, or plaster of Paris, is lime combined with sulphuric acid, and is therefore called *sulphate of lime.*

In Sicily and some other parts of the world, sulphur is found in masses or layers, between clay and marl formations. In such cases it is usually accompanied by gypsum, rock-salt, or peat. Sicily is well known to be the sulphur-market of the world. It is obtained by putting the clayey marl containing it in stoves or ovens, with an inclined bottom which terminates in a canal; the sulphur, as it melts, thus flows into vessels prepared to receive it.

Many springs contain sulphur, dissolved and combined with hydrogen gas, which, on escaping, a precipitate of sulphur ensues. Such springs exist at Avon in this state, and at Fauquier, and many places in Green Brier county and other parts of Virginia, near St. Louis, in Missouri, &c. We generally find sediments and deposites of sulphur in the vicinity or on the borders of such springs. Such waters are very efficacious in the cure of cutaneous and other chronic affections.

Sulphur is disseminated throughout the ocean, as it forms a constant ingredient in sulphate of soda, which is a constant ingredient of salt water.

Chlorine derives its chief importance from the fact that, in combination with hydrogen, it forms *muriatic acid*, which, united with soda, forms the *muriate of soda*, or common *sea* or *table salt.* This forms about 2.5 per cent. of sea-water. Of course rock salt contains an immense quantity of chlorine

spectacle is presented; the floor, which burns with a blue flame, consists of sulphur mixed with earthy matter."

and muriate of magnesia and muriate of lime, both of which exist in the waters of the ocean, contain a considerable quantity. One remarkable property of chlorine is, that it discharges all vegetable colours; hence it is extensively employed for bleaching.

Fluorine does not exist to any great extent. In combination with hydrogen it forms *fluoric acid*, which is most often met with in *fluor spar* or *fluate* of *lime*, a very interesting mineral, not only on account of its beautifully variegated colours, but also on account of the varied form of its crystals. Fluorine exists in small quantity also in mica, hornblende, feldspar, greenstone, &c.

Phosphorus abounds in nature to a limited extent, and is, for the most part, met with in the bones of animals. Human bones contain about 51 per cent. of phosphate of lime, and the enamel of the teeth 78 per cent. of the same substance. It has been ascertained by Dr. Turner, that the fossil bones of animals contain phosphorus; and he obtained from the rib and tooth of an ichthyosaurus 50 per cent. of phosphate of lime. This substance, when pure, inflames when exposed to the atmospheric air.

The *metallic bases of the alkalies and earths* are of considerable importance in geology. Of these* *silicium* is by far the most abundant on the surface of our planet, as it enters largely into the composition both of the chemical and mechanical rocks. Silica is contained in the rocks enumerated beneath in the following proportions:

* It is now maintained by some that silicium is not a metal. Thomson ranks it with boron and carbon, and calls it *silicon*. It wants the metallic lustre, and is a non-conductor of electrici ty, properties incompatible with its being a metal. The question may, however, as yet, be considered as unsettled.

	per cent.
Gneiss . .	70 to 71 + 47 oxygen.
Mica slate . .	61 " 73 + 44 do.
Hornblende rock .	54
Chlorite slate . .	63
Talcose slate . . .	78
Compact feldspar .	51 to 60 + 46 oxygen.
Granite . . .	63 " 74 + 48 do.
Schorl rock . . .	68
Greenstone . . .	54 + 43 oxygen.
Hypersthene rock .	59 to 61
Basalt . . .	44 " 59 + 43 oxygen.
Pitchstone . .	72 " 73
Serpentine . .	42 " 43
Diallage rock .	58 " 60

In pure rock crystal or quartz, silica is nearly the sole ingredient. In limestone we often find silica disseminated ; and this is the reason why such limestone does not form good lime ; the silica, by burning, combines with the lime, forming *silicate of lime*. *Silica*, in the form of rounded flint nodules, is often met with in beds of chalk ; in many places these nodules constitute one third of the whole mass.

Aluminium is the next most important base of the earths on the surface of the earth. It is diffused as widely, though not so abundantly, as silicium. It constitutes the base of the various clays and argillaceous slates, and often exists in limestone, rendering it very valuable, in consequence, for water-setting purposes. It exists in the rocks enumerated beneath in the following proportions :

Gneiss	15	per cent.
Mica slate	15	"
Hornblende rock . .	15	"
Chlorite slate . . .	8	"
Talcose slate . . .	13	"
Compact feldspar . .	30	"
Granite	14	"
Schorl rock . . .	17	"
Greenstone . . .	15	"
Hypersthene rock . .	10	"
Basalt	16	"
Pitchstone . . .	11	"
Diallage rock . . .	13	"

The mechanical rocks nearly all contain alumina.

Potassium and *sodium* are pretty widely disseminated among rocks, though not in very large quantities. Potash is the most abundant of the two, and is also contained in vegetables, which derive it, however, from the decomposition of rocks containing it. Nearly all the inferior stratified rocks contain potash, generally from five to ten per cent. Granite contains about seven per cent., and greenstone, and rocks of that class, about the same proportion. *Soda* is chiefly disseminated in the ocean, in the form of muriate of soda, and also in rock salt, which, in Poland and other countries, constitutes immense beds. It is also found in certain feldspars, in schorl, basalt, pitchstone, hypersthene, &c.

Magnesium, the metallic base of magnesia, is present in all the inferior stratified rocks, with the exception of quartz rock and a few feldspars. There are very few limestones which do not contain it; such are called magnesian limestones. In *dolomite* it forms more than 40 per cent. Magnesia abounds in the waters of the ocean, in the form of a muriate of magnesia.

Calcium, the metallic base of lime, is found in numerous rocks besides limestone, such as granite, gneiss, mica slate, chlorite slate, talcose slate, clay slate, hornblende rock, &c. Lime also abounds among the fossiliferous rocks in the form of a carbonate. It is also disseminated through sea-waters, though in small quantities.

Imponderable agents.—These are *heat*, *light*, *electricity*, and *galvanism*. Of these, the first is of the most importance in a geological view, as it is continually effecting changes on the surface of our earth. By heat or *caloric* is generally understood the effect of hot bodies on our senses. When this sensation is excited to a high degree, it is called *burning*. Thus the term heat has two meanings;

one, the *feeling* experienced on touching a hot body, the other the *cause* of that sensation.

The degree of heat which a body gives out is called its *temperature*. All substances in nature contain heat, whether solid, liquid, or aeriform, even when they appear cold to the touch; for, by exposing them to a greater degree of cold, we can prove that it is extracted from them. If we suppose heat to be material, its particles repel each other, and are attracted by all other substances. Thus, caloric diffuses itself among all bodies with which it comes in contact, until they are all of the same temperature, although they may contain different quantities of heat. Thus, if we seize a heated body, its heat passes to the hand; if a cold one, the heat of the hand passes to the cold body. There is a great difference in the conducting properties of bodies, which causes a piece of marble, for example, to feel colder than a piece of wood, though both are of the same temperature. Thus heat may be communicated by *contact;* by *radiation*, where it passes through the air; and by *conduction*, where it is transmitted from particle to particle of the same substance.

The *sun* is the great source of heat as well as light. It is generally believed that the sun is a great body of fire; but, since Herschel's discoveries, it is considered by philosophers an inhabitable world, and that the light and heat which it gives out are occasioned by the decomposition of certain elastic fluids. *Latent caloric* is distinguished from *free* caloric in not being perceptible to our senses. That a cold bar of iron contains caloric is proved by hammering it on an anvil for a few minutes, when it will be brought to a red heat. So also fire can be produced by rubbing two sticks of wood together. If we turn aquafortis on to sulphuric acid, and then pour the mixture into a vessel of oil of turpentine, the whole mass will burst out into a flame. So also flame can be produced by mixing together two aeriform substances.* In all these cases, by chemical mixture, the *capacity for caloric* is diminished, and of course it escapes. We see the same thing proved by the well-known fact that different substances require different degrees of heat to bring them to the same temperature. Thus a pound of water requires 20 times as much heat to bring it to the same temperature as a pound of quicksilver.

We have stated that bodies differ in their power of transmitting caloric. Metals, for example, are better conductors than substances of less density, as wood, wool, feathers, paper, &c. For this reason metallic tools, which are to be used when heated, are furnished with wooden handles, or covered with cloth or paper. If we take into the hand a piece of lead and a piece of cork which have been immersed for a few minutes in boiling water, we shall find the cork but slightly warm, while the metal will be so hot that it cannot be held. A geological fact connected with this subject was discovered in 1829, so marvellous in its nature that it seems almost incredible. A mass of ice was discovered under a thick cover of lava on Mount Ætna, which had remained there ever since the lava had flowed out in its melted state! On investigating the cause, it was found that the ice had been covered with volcanic sand, which is one of the best non-conductors of caloric, and so had been protected from the heat of the lava. The shepherds on Mount Ætna preserve snow for the refreshment of their flocks during the summer by covering it with the same kind of sand.

* When air is violently compressed, it becomes so hot as to ignite cotton and other substances. An ingenious instrument for producing a light for domestic uses has been constructed, consisting of a small cylinder in which a solid piston moves air-tight; a little tinder or dry sponge is attached to the bottom of the piston, which is then violently forced into the cylinder; the air between the bottom of the cylinder and the piston becomes intensely compressed, and evolves so much heat as to light the tinder.

It is owing to the different conducting powers of minerals that they occasion different sensations when touched. Thus a piece of topaz or rock-crystal can be distinguished from a piece of polished limestone by its colder feel. "The method of making ice and cooling water in hot climates depends on the principles of the conduction of heat. In the European settlements of Bengal, on the banks of the Ganges, the cold is so slight that even during the winter, which lasts about six weeks, there is no fire kindled in any house except for culinary purposes. Ice is procured from the neighbouring mountains, and the natives have a peculiar method of producing it in larger quantities. They dig pits in the earth, lay straw in them, and set round uncovered vessels of burned earth on it. The vessels are filled with water, and, after sundown, small pieces of ice are thrown in: the next morning, before sunrise, the vessels, the water in which is frozen, are removed." On the same principle, water or wine is cooled by wrapping vessels round with a wet cloth and placing them in the sun; evaporation of the fluid soon reduces the temperature of the contents of the vessel.

We clearly perceive the wisdom and goodness of Providence, in imparting to bodies gradations of power to conduct heat, in the case of snow and ice. Were it not for the protection of snow, which is a poor conductor of caloric, winter grain and grasses would inevitably be killed, and in northern latitudes the earth would be frozen to such a depth that the heat of summer would not be able to thaw it sufficient for the purposes of cultivation.

It is a physical law, to which Dr. Lardner states there is no *real* exception,* that heat expands all

* In baking bricks it has been supposed that there was an exception to this law that heat expands all bodies, as the brick, when baked, occupies smaller space than before. But this is owing to the expulsion of the water by the heat; so that we

bodies. This may be illustrated by the following examples: If a flaccid bladder be tied at the mouth and held near the fire, it will swell and become fully distended by the rarefaction of the contained air. In fixing the tire on to the wheels of carriages, the rim of iron is made at first of a diameter somewhat less than that of the wheel; but, by being afterward heated, its circumference is so much increased that it will be sufficient to embrace and surround the wheel. When placed upon the wheel, it is cooled, and, suddenly contracting its dimensions, binds the wheel firmly together, and becomes securely fixed in its place. If the stopper of a glass bottle or decanter becomes so firmly fixed in its place that it cannot easily be removed, by wrapping the neck of the vessel round with a cloth dipped in hot water, we cause the glass to expand, and the neck will be enlarged so as to allow the stopper to be easily withdrawn.*

By the application of the same principle, the walls of a large building, which had been forced out of the perpendicular by the weight of the roof were drawn together by heating bars of iron, which were placed across the building at right angles to the walls. By means of nuts screwed on their ends outside of the building, which were tightened as the rods were alternately heated and cooled, the walls were easily drawn into their original perpendicularity. As air or water become heated, they become lighter and ascend; in this manner water is made to boil, the air of our rooms becomes uniformly warmed, and the atmosphere is purified by the incessant motion caused by rarefaction. Thus we

perceive it is not at all strange that a quantity of water and clay should occupy a larger space than the clay alone. Thus the elastic vapour of steam occupies more space than the water when condensed.

* Lectures on Geology, by Von Leonhard, translated by Morris, p. 61.

perceive that the form of bodies is dependant on heat. By its increase solids are converted into liquids, and liquids are dissipated in vapour; by its decrease vapours are condensed into liquids, and these become solid. If matter ceased to be under the influence of heat, all liquids, vapours, and, doubtless, even gases, would become permanently solid, and all motion on the surface of the earth would be arrested.*

Now, as there is a continual change of temperature in all bodies on the surface of the globe, it follows that there is a continued change of magnitude. The substances surrounding us are constantly swelling and contracting under the vicissitudes of heat and cold. They grow smaller in winter and larger in summer. They swell their bulk in a warm day and contract it in a cold one. Thus we see that in warm weather the flesh swells and the vessels appear filled; in cold weather the flesh contracts, the vessels shrink, and the skin shrivels.

When water freezes it becomes lighter, and therefore swims; were it not for this circumstance, our lakes and rivers would all become solid bodies of ice during the winter. Caloric is given from substances when freezing, which tends to mitigate the severity of cold. For this reason we feel warmer after a heavy fall of snow. Ice thaws very gradually; were it not so, the most alarming inundations would follow.

Heat is measured by means of the *thermometer*. This is merely a graduated glass tube, containing quicksilver, alcohol, or other substances which do not readily freeze. After the fluid is introduced, the air is expelled by heating the bulb, when the tube is hermetically sealed; then, by immersing it in boiling water, the mercury rises to a certain point, which is marked; afterward it is immersed in a

* Turner's Chemistry.

freezing mixture, when the mercury falls to a fixed point, and this point is marked; then the intermediate space is graduated, according as convenience or fancy may dictate. In Fahrenheit's thermometer, the freezing-point is marked at 32, and the boiling-point of water at 212, making the intermediate space 180. The reason he did this was, that as he thought, by mixing sal ammoniac and snow, he could produce the greatest degree of cold, he marked this by 0, and from this point divided his scale into 212 degrees, of which 32 extend to the freezing-point of water, and the remaining 180 to the boiling-point of water.

Before concluding our remarks on the chemistry of the globe, it is necessary to consider some of the laws of chemical combination, those laws which bind the materials of this earth into a consolidated mass.

All chemical phenomena are owing to *affinity* or *chemical attraction*. It is this which causes the minutest particles of different kinds of matter to combine, so as to form new bodies endowed with entire new properties. It acts only at insensible distances, and in this respect differs from the physical laws described in the last chapter. In order to chemical union, the particles of matter must actually be in contact; for, if removed to ever so small a distance, they will not unite. If two bodies brought together do not unite, they form a *mechanical mixture*. Thus, if we mix iron filings and powdered sulphur together, they do not combine, but form a mixture; if we apply heat to them, however, they melt, and, by a chemical combination, produce a substance different from either of the former. So, also, oil and water *mix*, but do not chemically combine; while water and sulphuric acid combine readily. That power which draws the particles of matter together so as to form large masses, like rocks, is called *cohesion*, *cohesive attraction*, or the *attraction of aggre-*

gation. This, like chemical affinity, exerts its influence only at insensible and infinitely small distances, as we perceive when we attempt to unite the broken fragments of a piece of marble or a metallic wire. It differs, also, from affinity in this, that while it tends to unite *similar* particles, chemical attraction is exerted between dissimilar particles. *Lime* and *carbonic acid*, which together constitute limestone, differ from each other as well as from marble, and are united by chemical affinity; while a piece of marble is an aggregate of smaller portions, attached to each other by *cohesion*, and the parts so attached are called *integrant particles*. The lime and the carbonic acid are called the *component* or *constituent* parts; thus we perceive that the former are aggregated by *cohesion*, the latter by *affinity*.

The hardness and toughness of minerals is proportionate to the strength with which their particles cohere. Cohesion may be destroyed by mechanical division or by the application of heat; and both these means are employed in the reduction of ores, and the conversion of limestone into lime. The former is useful by increasing the extent of surface exposed to the influence of heat, and heat is essential in bringing bodies into that state of liquefaction necessary for chemical union. A larger portion of salts is dissolved in a certain amount of warm water than in the same quantity of cold, because the *cohesion* of the salts is diminished by the heat. Cohesion may often be restored when lost, as when melted sulphur or lead is again cooled, or the water containing salts in solution has been evaporated. If we dip an iron wire in water, we find on taking it out that some particles of water adhere to it. If we dip it in quicksilver, we find there is no adhesion of its particles. If we turn quicksilver into a bowl of glass or earthen, the surface will appear convex, because there is no attraction between the metal and the sides of the bowl; but if we turn the same into a metallic vessel, the surface will be hollow or concave, because the metal is attracted by the sides of the vessel. A gold coin dipped in quicksilver will be so coated with it in a short time that it cannot be wiped off. An *amalgam* is formed by chemical affinity, and the gold becomes soft and white. So pieces of tin, placed upon melted lead, will swim, because *specifically lighter* than lead; but on melting, which it will in a short time, we find it diffused, by the influence of affinity, through every portion of the lead. If we throw rock-salt into water, it sinks; in a few minutes it is dissolved, and we then find every particle of the water impregnated with salt. It has been attracted in every direction by chemical affinity. The same is the case with sugar, and every other substance which has an affinity for water. When we mix alcohol and water together, at first we find a mere mechanical mixture; in a short time, however, the fluid appears uniformly the same, because they have chemically combined.

Remarkable changes occur by the combination of different substances. If we mix *copper*, which is of a *reddish* colour, with tin, which is *white*, we have a compound of a *grayish yellow* of a very hard texture, although both copper and tin are soft. And, what is more singular, though copper is not one of the heavy metals, and tin is lighter still, the combined mass weighs more than both. Now *bell-metal* is made of tin and copper; though a bell of tin would have no sound, and one of copper would sound duller yet. The same compound constitutes *bronze*, of which cannon, speculum, statues, &c., are cast. Tin, combined with lead, forms one of the best solders. *Pewter* is an alloy of tin 100 parts, and antimony 17 parts.

The air we breathe is composed of two poisonous gases; and table salt is the result of a combination of two powerful poisons (*chlorine* and *sodium*).

When different substances are brought together, the results will vary according to the peculiar properties of each. Decompositions of one or more will take place, and new compounds be formed, and on this fact is founded the doctrine of *elective affinity*. To illustrate: Many years ago, some workmen employed in the copper-mines of Wicklow left their iron shovels in a place where they were exposed to running water containing copper in solution. The result was, that the shovels, when found some time after, were covered with copper to such an extent, that the workmen were induced to believe that they had been wholly changed into copper. In consequence of this fact being observed, about 500 tons of iron were introduced into the mines, and at the end of a year the iron was found dissolved; every ton of iron produced a ton, sometimes a ton and a half, and even two tons, of metallic precipitate; and from each ton of this substance were produced 16 cwt. of pure copper.* This circumstance was owing to the fact that the copper was dissolved in sulphuric acid; and as this acid has a stronger affinity for iron than for copper, it united with the former, leaving the copper adherent to its surface. This experiment is easily performed by dissolving a bit of copper in sulphuric acid, and immersing in it a piece of iron. *Compound elective affinity* is where a double decomposition takes place; as, for example, if we mix together sulphate of potassa and nitrate of soda, there result sulphate of soda and nitrate of potassa, the sulphuric acid leaving the potash and uniting with the soda, and the nitric acid leaving the soda and uniting with the potash. This is a complex operation, but one which we witness every day. If we turn a solution of camphor into

* Von Leonhard's Lectures.

water, the camphor will be set free, because the alcohol combines with the water. So, also, all the gum resins which are insoluble in water are liberated in the same manner. Sulphuric acid has an affinity for the following substances, in the order in which they are arranged.

Baryta.	Soda.
Strontia.	Lime.
Potassa.	Ammonia.

Magnesia.

Sulphuric acid will be separated from any of these bodies by adding any one above. For example, it is separated from magnesia by ammonia, from ammonia by lime, &c., but none can withdraw it from baryta. Geological phenomena furnish numerous instances of simple and compound elective affinity, which we shall hereafter find occasion to notice; in the mean time, we must pass on to other subjects. There are numerous other points of great interest connected with chemistry, which it might be profitable to dwell upon did our limits permit. We have only alluded, and that in a very cursory manner, to such laws and principles as are absolutely essential to an intelligible comprehension of geological phenomena; and the more thoroughly these principles are studied and understood, the more attractive and interesting will the science of geology appear.

CHAPTER III.

MINERALOGICAL CONSTITUTION OF THE EARTH'S SURFACE.

Simple Minerals: Quartz, Feldspar, Mica, Talc, Chlorite, Horn blende, Serpentine, Limestone, Slate and Clay, and Augite —Minerals found in Veins or Beds: Iron, Lead, Gold, Silver Tin, Copper, Zinc, Mercury, Manganese, Titonium, Bismuth, Antimony, Cobalt.

We have now described, in a very brief manner, some of the elementary substances of which the solid as well as fluid matter of the earth is composed; and we have found that the four earths, *silex*, *alumine*, *lime*, and *magnesia*, constitute at least nineteen parts out of twenty of the known solid matter of the globe, variously intermixed and aggregated together. These materials form the chief proportion of all loose soils, and also of the softer species of stone, which are, in fact, the same substances in a more compact form. Thus most kinds of sandstone are nothing more than loose sands or silex cemented together; the softer kinds of slates, or those which readily soften and crumble away on exposure to air and moisture, are nothing more than indurated clays or alumine; and those kinds of limestone which may be readily cut and worked are almost the same thing as chalk, but in a state of greater induration; while *marl*, which is often very hard when first taken from the ground, is merely an indurated admixture of argillaceous and calcareous matter.* Although the varieties of stones and rocks appear to be so numerous, yet, on examination, we shall find that the simple minerals

* Burr's Practical Geology.

of which they are composed are very few, and can be learned by any one in a very short time.

The most important of these are the following, viz.:

1. Quartz.	6. Hornblende.
2. Feldspar.	7. Serpentine.
3. Mica.	8. Limestone.
4. Talc.	9. Slate and Clay.
5. Chlorite.	10. Augite.

1. *Quartz* is one of the hardest minerals of which rocks are composed, and consists almost entirely of silex. It gives sparks with steel; breaks into sharp, angular fragments by the blow of a hammer, leaving a smooth, shining surface, like glass. Hence the fracture is called *vitreous*. Quartz readily scratches glass, and, indeed, most other minerals; it is infusible when unmixed, but with alkalis it melts easily and forms glass. Its colours are various shades of white, gray, brown, yellow, red, and green. When rubbed, it yields a phosphorescent light, and often a peculiar odour. It is not acted on by any acid except the *fluoric*. Quartz often occurs in a crystallized form. The most common forms of the crystals are six-sided prisms, terminated by six-sided pyramids, thus:

Fig. 1.

Quartz sometimes forms large beds, and even mountains, though it more generally, perhaps, exists in veins intersecting other rocks. It forms the great bulk of sandstones and gravel-beds. There are numerous species of quartz, such as flint, opal, chalcedony, carnelion, agate, jasper, hornstone, garnet, idocrase, stilbite, zeolite, zoisite, epidote, &c. Most of the precious stones employed by the lapidary for gems are varieties of quartz.

Felspar or feldspar* is a very common mineral,

* Field-spar. German.

and forms a constituent part of numerous rocks. It is not as hard as quartz, but more brittle. It is composed of thin laminæ or plates, which are most commonly four or six sided prisms, which have a bright, pearly lustre, which distinguishes it from quartz, whose lustre is dull.

Fig. 2.

An oblique parallelopiped, the primitive form of feldspar.

The colours of feldspar are white, gray, milk-white, yellowish or reddish white, sometimes inclining to green. When crystallized it is translucent. It may be melted into a glass without adding any alkali, because an alkali forms one of its constituent ingredients. It is found, on analysis, to contain silex 63; alumine 17; potash 13; lime 3; oxide of iron 1: it is probably owing to the fact that feldspar contains potash that it is so easily decomposed, although nearly as hard as quartz. Those feldspars which do not decay on exposure to the atmosphere contain but little, if any, potash. When decomposed it forms a kind of clay called *kaolin*, from which china or porcelain-ware is made by burning. In its manufacture a little lime is added as a *flux*, which tends to soften it in the fire, and, on cooling, it assumes the requisite degree of hardness. Feldspar forms a constituent part of granite, gneiss, and mica slate, and enters more or less into the formation of greenstone and most volcanic substances, as well as porphyry and sienite. In some parts of the world it forms entire mountains; as in Siberia, Scotland, Labrador, &c.

Mica,* sometimes called isinglass, is also composed of silex, alumine, potash, and oxide of iron.

* From the Latin *micans*, shining.

It consists of extremely thin parallel plates, having a bright metallic lustre; its colour is yellow, gray, blackish green, white, and brown. The plates are very elastic, which distinguishes it from talc, which in some respects resembles it. As the plates are transparent like glass, it is often used for doors in lanterns, and for windows in ships, where a more brittle material, like glass, would be liable to be broken; as it will bear heat without injury, it is also used in stoves. Mica is soft, and may be easily scratched with a knife. It sometimes crystallizes in six-sided prisms. It forms an essential ingredient in granite, gneiss, and mica slate, and is accordingly abundant in every primitive country. In Siberia it is quarried, and employed for the same purposes as glass. Plates of it three feet square have been brought from that country.

Talc bears some resemblance to mica, but is unctuous to the touch, and not elastic, though flexible. It is also softer than mica, and is infusible, while mica may be melted by the blowpipe into an enamel. It is either of a greenish or a silvery white colour, and has a shining, pearly lustre. It is found in primitive rocks, such as granite and serpentine, but is not an abundant mineral.

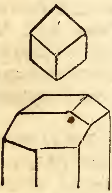
*Chlorite.**—This mineral closely resembles talc, is of a darkish, dull green colour, has a glistening lustre, and is soft and rather soapy to the feel. It seems to be composed of a compact mass of minute scales. In its chemical composition, it contains less silex, but more magnesia than talc. Chlorite slate is one variety of this mineral; and this is found in beds in primitive mountains, and sometimes contains crystals of mica, garnets, magnetic iron, &c.

Hornblende is of a dark green or black colour, heavier, but less hard than quartz or feldspar; it

* From *chloros*, green.

may be scratched with a knife, and the colour of the streak is a light green. It easily melts into a black glass, and is often found crystallized in an irregular manner. Hornblende forms a constituent part of many rocks, end even forms entire mountains or slaty beds in mountains. It enters largely into the rocks of volcanic origin, such as greenstone, basalt, &c., generally denominated *trap rocks* The chemical composition of hornblende, basalt, and lava, is very similar.

Fig. 3.



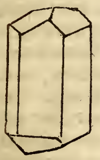
Hornblende often occurs in a crystallized form, as in the margin, though it is more often met with in rude, shapeless masses. We often see it composed of long, needle-shaped or acicular crystals, diverging from a centre, which are star-shaped or radiated like the spokes of a wheel, and the lustre is shining.

Serpentine.—This is one of the magnesian minerals, being composed of from 20 to 45 per cent. of silex, 18 to 23 per cent. of alumine, and 23 to 34 of magnesia, and 8 to 12 of water, with a trace of iron, to which its colours are often owing. It derives its name from its resemblance to a serpent's skin, being streaked or spotted. Bakewell thinks that it may be regarded as an intimate combination of hornblende with talc or chlorite; whether this be the case or not, it is certain that there is an intimate connexion between them, and that we often find hornblende changed into serpentine when in contact with limestone. Serpentine is generally compact, nearly granular, yields to the knife, is somewhat soapy to the feel, and is susceptible of a high polish. It is often employed as a marble; and, when limestones containing it are polished, they consitute what is called the *verd antique marble.* This mineral forms extensive beds, and is the repository of the chrome iron, from which is manufactured the paint called chromate of lead, or chrome yellow.

Limestone.—When pure, limestone is composed of about 57 parts of lime and 43 carbonic acid; but there is often intermixed with it magnesia, alumine, silex, or iron. This mineral may be scraped with a knife, and effervesces by the application of strong acids, and can be entirely dissolved in nitre or muriatic acid. Common limestone, then, is a *carbonate of lime*, while gypsum is a *sulphate of lime*. Limestone occurs of every variety of colour; and its texture varies from the most compact and solid marble, to a fine earthy powder like marl or chalk. It crystallizes in a variety of forms, some writers say as many as seven hundred, though, on splitting them, the same primitive form, *a rhomboid*, is obtained from them all. This is a solid, having, as in the adjoining figure, all its faces equal to each other, but the angles not right angles. When carbonate of lime is crystallized, it is called *calcareous spar*, possessing the property of double refraction, and of becoming electric by friction. Another form in which it crystallizes is the six-sided prism, as in fig 5. Limestone is a very common mineral in almost every country, forming extensive beds and even mountains. The granular and compact varieties are used for marble or for making lime; chalk is used for marking, making lime, and whiting, and marl is highly useful as a manure.

Fig. 4.

Fig. 5.



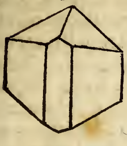
Gypsum, or sulphate of lime, is a compound of oil of vitriol, or sulphuric acid and lime, with a little water. It is less abundant than the carbonate, but forms beds of considerable thickness and extent. It is usually white, though sometimes tinged with gray, red, and other colours. Common plaster of Paris has a laminated or granular structure, and is sometimes compact. It is softer than common limestone, and can be easily scratched with the nail. It does not efferversce with acids. Its constituent parts are, lime 32, sulphuric acid 46, water 31. There is a variety which contains no water, and is therefore called *anhydrous.* When crystallized, gypsum can be separated into thin plates, like mica and talc, which break into four-sided crystals, as in fig. 6. This mineral is used for various purposes, such as a manure, for cements, castings, &c. It is generally found in connexion with salt-springs or rock-salt.

Fig. 6.

Slate and clay.—By the term *slate*, when employed alone, is understood *clay slate*, or what is sometimes called argillaceous *schistus*, known generally by the name of *roof slate*, as it is used for that purpose. It consists of silex 48, alumine 23, and sometimes a little carbon, potash, water, and oxide of iron. It is easily scratched by the knife, and on moistening, by breathing on it, gives out a peculiar odour. Its colours are usually bluish, greenish, gray, or reddish. The slate rocks have generally a slaty structure, and may be split in two directions, which have an acute angle with each other; but some varieties cannot be split in any direction. On account of the potash contained in some species of slate, it is easily decomposed on exposure to the atmosphere, forming a clayey soil of great fertility. What is called *shale* by the English miners is only a soft, dark-coloured slate, containing more carbon than common slate. Slate is employed for roofing buildings, drawing slates, and pencils, and the clays for making bricks and pottery. The clays are of the same chymical composition as slate. Both are very abundant.

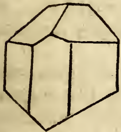
Augite.—This is not a very abundant mineral, except among volcanic rocks. It is composed of silex, lime, and magnesia, and is usually dark brown, black, or green, but sometimes light coloured. It resembles hornblende, but is much harder, and strikes fire with steel. It crystallizes in short four-sided or six-sided prisms, terminated by two faces, as in the adjoining figures.

Fig. 7.



Augite is found in considerable abundance in volcanic rocks, and in some of the trap rocks, which are generally supposed to be of volcanic origin. It is met with also among primitive rocks. It often exists in a granular or massive form; when granular, it is called *coccolite*, from "*coccos*," a grain.

Fig. 8.



Minerals found in veins or beds.—The metallic and other minerals which are occasionally interspersed throughout the mass of earths, or more generally forming veins or beds of limited extent, are far more numerous, and present a wide range of study to the mineralogist; but the limits of the present work forbid our entering upon this branch of natural science in detail. It is, however, necessary to notice such as are most common, and which it is absolutely necessary for the geologist to be able to recognise whenever he may see them. These are the ores of iron, lead, gold, silver, tin, copper, and zinc; mercury, manganese, titanium, bismuth, antimony, and cobalt, also occur. Many of these are comparatively rare.

These are all metallic minerals, and may be distinguished from the earthy by their possessing a brilliant metallic lustre and great specific gravity.

Iron.—Of all metallic minerals, *iron* is by far the most abundant and most generally distributed; there is, indeed, scarcely a rock or soil in which it does not occur. Its ores are numerous, but the most important are *iron pyrites*, *oxide of iron*, and *clay iron-stone*.

Iron pyrites is composed of iron and sulphur in nearly equal proportions; it is brilliant, of a pale brass-yellow colour, and generally crystallized often in cubes. It scratches glass, and gives fire with steel, and is often taken by the ignorant for gold. This variety is apt to suffer decomposition from exposure to the air, becoming covered with a white efflorescence, which is a *sulphate* of iron or copperas. In several places in the United States the manufacture of copperas from this mineral is carried on; at Strafford, Vermont, in the year 1825, nearly a thousand tons of copperas were produced.

Oxide of iron is iron combined with oxygen, and differs much in appearance, according to the degree of oxidation and intermixture with other substances; some varieties being red and earthy, others of a dark brown colour, others of a steel gray, with a bright metallic lustre; the latter is termed specular iron. Iron in the state of the protoxide is highly magnetic, and forms the native *loadstone*, but in the state of the peroxide it loses its magnetic qualities.

Clay iron-stone is a very impure carbonate of iron; it is generally of a light brown colour, and occurs in large nodular masses in connexion with coal-beds, and also forming deposites in sandstones.

Masses of *native iron*, which is malleable and flexible, and contains a small quantity of nickel, have been found in various parts of the earth; one of which, discovered in Louisiana, and now in the Mineralogical Cabinet at New-Haven, weighs upward of 3000 pounds. A mass is also in the Imperial Cabinet at Vienna, which was seen by the inhabitants to fall from the air in the shape of a globe of fire.

Lead.—The colour of this metal is a bluish gray, which soon tarnishes on exposure to the air. Its ores are numerous, but, with the exception of the sulphuret of lead or *Galena*, they are of great importance. Lead is used, in its metallic state, for the construction of aqueducts, covering the roofs of houses, the composition of amalgams, as pewter, &c.; its oxides and salts are employed as paints, in the composition of glass, in medicine, and in several of the more common arts. Galena occurs both granular, compact, and crystallized, and is the variety which is so extensively worked in Missouri and other parts of the Union.

Gold is only found in the native* state, though often alloyed with other metals. It is of a bright orange yellow, and does not tarnish on exposure to the air like iron pyrites. It is found in granite, quartz, slate, hornstone, sandstone, and limestone; also in veins of iron ore, antimony, barytes, blende (zinc), and especially in alluvial soils. The gold of commerce is chiefly found in alluvial deposites, where it occurs in small particles or grains, called *gold dust*. Thus the gold-mines of Brazil and Africa are entirely on the surface, the gold being separated from the sand and gravel among which it is found by washing. In Brazil alone, according to Maowe, above 20 tons weight of gold ore is annually procured, which forms a large portion of the metallic circulation of the world. The gold-dust of Africa is an extensive article of commerce.

Gold has sometimes been found in masses of considerable size. In 1730, a mass was found in Peru weighing 45 pounds. In Paraguay, several masses have been found weighing from 20 to 50 pounds. A mass was once found in North Carolina, according to Cleaveland, which weighed 28 pounds.

The gold-mines of the United States are chiefly confined to North Carolina, where they are spread over a space of not less than a thousand square

* By this term is meant a state in which the metal is malleable or *workable* without refining or roasting.

miles. The prevailing rock in the gold region is argillite.

Silver.—This metal occurs both native and combined with sulphur and muriatic acid, forming *sulphuret* and *muriate* of *silver.* Its colour is white, often tarnished gray or reddish; melts into globule, and, when dissolved in nitric acid, tinges the skin indelibly black. It occurs in Saxony and Suabia in gneiss and mica slate; also in Bohemia, Norway, Ireland, England, South America, Huntington (Connecticut), and, generally, in small quantities, in all lead ores.

In some instances large masses have been found; as in Saxony, where a mass weighing 125 pounds was discovered; and another in the mines of Kensberg, which weighed 560 lbs.; and Jameson mentions a block of the same metal, discovered in the mine of Schneebergh, in Saxony, which was so large that Duke Albert descended into the mine and made use of it as a dinner-table. This mass, when smelted, produced 44,000 pounds of pure silver.

*Tin** is a white metal of considerable lustre, and generally occurs massive, in the form of an oxide. Sometimes it is found in fine brilliant crystals of various forms. It only occurs in primitive rocks, as in Cornwall (Eng.), Spain, Bohemia and Saxony, Mexico and Peru, &c. Some of the Cornwall mines extend many hundred feet under the sea, and it is said that in one of them the noise of the waves and the rolling of the pebbles can be distinctly heard, so near has the excavation been carried to the bottom of the ocean.

Tin is employed for various purposes. Thin sheets of iron, being dipped into melted tin, receive a coat of the metal, and are thus prevented from rusting. This, commonly called *sheet tin*, is the article of which the common tinware is made. Tin

* Comstock's Geology

foil, with mercury, forms the amalgam on the backs of looking-glasses.

Copper is found native, also combined with several substances, such as sulphur, oxygen, the different mineral acids, and several of the other metals. Next to iron, it is the most indispensable to the wants of man. *Brass* is a compound of copper and zinc. Bell-metal, bronze, pinchbeck, speculum metal, &c., are always of copper, with various other metals. Its salts and oxides are employed as paints; also for enamelling, &c. There are many varieties of copper ore, the most common of which are *copper pyrites*, or "yellow copper ore" (a sulphuret of copper), and the *carbonate of copper*, of which there are two varieties, the *blue* and *green*. Copper ore has been found in several parts of the United States, as at the Perkiomen leadmine (Penn.), Schuyler's mines (N. J.), Cheshire (Conn.), Greenfield (Mass.), Blue Hills (Md.), Wethersfield (Conn.), and numerous other places. The great copper-mine of Fahlun, in Sweden, has been worked to the depth of 1200 feet, and one of the Cornwall copper-mines (Eng.) is 1800 feet deep.

Zinc generally occurs in the form of a *sulphuret* or blende; and is a dark brown or yellowish mineral, often occurring in fine brilliant crystallizations, though more generally massive; it is somewhat like tin ore, but less heavy.

Zinc is found in primitive and secondary rocks, and is associated with sulphuret of lead, iron, and copper. It is found in numerous places in the United States.

Manganese is always found in the state of an oxide; it generally appears as an earthy substance of a blackish colour, which yields readily to the knife, and is sometimes soft and friable. In its metallic state it has not been converted to any use; but, with muriate of soda and sulphuric acid, it forms a gas called *chlorine*, which is extensively employed in bleaching cotton, linen, paper, &c. When melted with borax, it always gives a purple tinge, by which it may be distinguished from iron and other substances. The other metals occur so rarely, and are of so little importance, that we shall pass them over; referring the reader, however, to Cleaveland, Comstock, Dana, and other authors who have treated of mineralogy, for any information in relation to them

CHAPTER IV.

PHYSICAL GEOGRAPHY OF THE EARTH.

Shape of the Earth.—Mean Density.—Ocean—Mean depth.—Saline Contents.—Mediterranean.—Temperature of Earth.—Reason for Supposing it has undergone a Change.—Central Heat.—Facts to Support such a Theory.—Influence of Climate on the Animal and Vegetable Kingdom.—Height of Mountains.—Highest Land in Asia.—In Europe.—In America.—Shape of Hills and Mountains.

The figure of the earth has been compared to that of an orange, being a flattened spheroid. The equatorial diameter is about 7924 miles.

The polar axis	"	7898 "
Difference		26 "

It can be demonstrated that a fluid body, possessed of rotatory motion in space, would assume a similar shape.

The *mean density* of the earth has been variously estimated, but, from experiments performed by different philosophers, it is now believed to be about five times greater than that of water, and, consequently, double that of the mineral crust of our globe.

Nearly three fourths of the whole surface of the earth is covered by water. Indeed, the Pacific Ocean alone covers a greater extent of square miles than the whole dry land with which we are acquainted. The mean depth of the ocean is estimated to be about three miles, and the mean height of the land above the ocean level, from a mile and a half to two miles; so that, as De la Beche observes, the present dry land might be distributed over the bottom of the ocean in such a manner that the whole globe would be covered by a mass of waters.

A very small portion only of the earth's surface is fitted for the habitation of man. Vast regions are covered by polar ice and snow, and by sandy deserts, steril mountains, marshes, rivers, and lakes, so that, it is believed, not more than one fifth of the globe is habitable. The other portions, it is true, are tenanted by various tribes and species of animated beings, "exulting in the pleasures of existence, independent of human control, and no way subservient to the necessities or caprices of man."

The waters of the ocean are more or less impregnated with salt, there being less at the surface than at some distance below, from the effects of evaporation and the fall of rain.* The saline contents vary from 3 to 4 per cent. These consist of common salt (*muriate of soda*), *sulphate of soda*, *muriate of magnesia*, and *muriate of lime*. The Mediterranean contains larger proportions of salt than the ocean; which is supposed to be owing to the fact, that the evaporation from its surface is greater than the quantity of fresh water with which it is supplied. This seems to be proved by the circumstance that two currents constantly flow into it, one from the Black Sea and the other from the Atlantic.

The temperature of the earth, which is mainly

* This is denied by Dr. Marcet, and some experiments of Mr Scoresby render it doubtful.

due to solar light and heat, decreases, as a general rule, in a regular gradation from the tropics to the poles. It is owing to the greater or less exposure to the sun that we have such a variety of seasons and of climates in different latitudes, and no one can contemplate this wise arrangement without enlarging his conceptions in regard to the wisdom and benevolence of the Supreme Being. From numerous geological phenomena, it has been concluded that the temperature of the earth has undergone important changes. This supposition rests chiefly on the discovery of vegetable and organic remains, imbedded in situations where, from the want of a congenial temperature, such animals or vegetables would now be unable to exist. For example, tropical plants and fossil elephants are found in great quantities in high northern latitudes, in such a state of preservation that it seems next to impossible that they could have been drifted there from a distance. In accounting for this phenomenon, Mr. Herschel, the astronomer, considers that a diminution of the surface temperature might arise from a change in the ellipticity of the earth's orbit, which, though slowly, gradually becomes more circular. Mr. Lyell, again, supposes that this decrease of temperature might arise from such a variation in the relative position of land and water, and in the elevation and form of land, as may cause the climate, in any given portion of the earth's surface, so to change, that a greater heat may precede a less heat, and the land be capable of supporting the vegetables and animals of hot climates at one time, and incapable of doing so at another. It supposes a combination of external and internal causes; the latter raising or depressing the land in the proper situations, the former supplying the necessary heat. This, though a highly ingenious theory, and not without some slight support from facts, is yet too improbable to meet with much favour. It cannot be denied, however, that there is abundant evidence to believe that a central heat exists, which exerts an important influence in maintaining the present temperature of the globe. This would seem to be proved by the existence of numerous active volcanoes; of rocks of igneous origin in various parts of the earth; and of numerous hot and warm springs, that preserve a uniform temperature for centuries. It is also rendered highly probable by numerous experiments made on the temperature of mines in Great Britain, France, Saxony, Switzerland, and Mexico, all of which go to prove that the temperature increases in proportion to the depth. M. Arrago also has shown, that in Artesian wells, which are borings by which water at different distances from the surface rises to, and even above the ground, from the pressure below, the temperature rises as we descend. "From numerous considerations," says Higgins, "it may be deduced that the temperature of the interior of the earth increases with the depth; and if this increase continued to the centre, all the mineral masses must be in a state of fusion at a very inconsiderable depth beneath the lowest rocks with which geologists are acquainted. Some philosophers have attempted to assign a limit to the increase of temperature; but, even according to their supposition, there are parts where the rocks are in a state of fusion, although the temperature cannot be raised higher. Strange, then, as it may appear, we are walking over a vast caldron of intumescent rocks, and are separated from it by only a thin crust, which is sometimes broken." From the result of all the observations hitherto made, we may safely conclude that the temperature increases as we descend at the rate of one degree of Fahrenheit for every eight fathoms; consequently, at a depth short of 100 miles, the materials of the globe are in a state of incandescence.

The influence of climate upon the vegetable and animal kingdom deserves a passing notice. It is in the torrid zone that we find birds of the largest size and gayest plumage; the largest and most powerful reptiles, as the crocodile, the alligator, and the boa constrictor; quadrupeds of immense size and strength, as the elephant, the rhinoceros, the lion, the tiger, and the giraffe. So also is the ocean distinguished in tropical climates by the production of shells, corals, and fishes peculiar to hot regions. There, too, vegetable productions attain their greatest luxuriance and variety; the palm, the sugar-cane, the coffee-tree, and the innumerable spice-bearing trees and shrubs, exhibit the most luxuriant types of vegetable life, the richest fruits and the most beautiful blossoms. As we go north this luxuriance disappears; animal and vegetable existence appear in less variety and in comparatively diminutive forms; and when we reach the polar circles, we are struck with the scantiness of animated creation, which is there represented by the reindeer and the polar bear upon the land, the whale and the medusæ on which it feeds in the ocean, while a few mosses and lichens compose the vegetation upon the frozen surface.

Height of mountains.—A large portion of the earth's surface is but slightly elevated above the ocean, especially upon the banks of great rivers and in extensive districts along the seashore. This is particularly the case in Holland, Northern Germany, and a large part of Russia; also in India and China, and other parts of Asia, and the valley of the Mississippi in North America. The highest land in Asia is the Himalaya Mountains, which rise to an elevation of more than 28,000 feet, or more than five miles above the level of the sea. On the island of Great Britain, the highest elevations are the Welsh Mountain, Snowdon, which rises to the height of 3571 feet, and Ben Nevis in Scotland, which is 4365 feet high. The highest land in Ireland is about 3405 feet above the sea. On the continent of Europe, the most elevated mountain is Mont Blanc, which forms the highest peak of the Alps, and rises 15,660 feet above the sea. The Pyrenees are about 11,000 feet high, and Etna is equally lofty.

In Africa, the highest mountains are those of Abyssinia, which are about 15,000 feet high. On our own continent, the highest points are those of the Andes; Chimborazo being elevated 21,425 feet, while several other peaks are equally lofty. The volcano of Popocatepetl, in Mexico, is 17,720 feet high; the Rocky Mountains* are stated to be probably still higher.

The external structure and configuration of hills and mountains forms a curious and interesting, although hitherto neglected branch of geological inquiry. These elevations have been shown to perform an important function in the economy of nature, by collecting and duly distributing over the earth's surface the waters derived from the atmosphere; and, to fit them for this office, a suitable structure has been given; a structure which is infinitely varied, according to the nature and composition of the mass. The more perfect representation of the undulations of the surface in modern maps, and, more especially, in those constructed for military purposes, will, however, in time, throw much light upon this subject, and more firmly establish those principles of which, at present, we have only a vague and general idea. As regards the direction of elevated ranges of ground, there is generally one or more extending through every continent and island, and thus determining its general form and configuration. The mountains of Great Britain present an example of this kind, and a still more striking one is afforded by the vast chain of mountains which

* 18,000 feet, according to Prof. Renwick.

traverses our own continent. Mountains and hilly ranges are not unfrequently parallel to each other; and, when viewed on the great scale, they often enclose vast tracts of country* within an irregularly curved area. With respect to the shape of hills or mountains, it is worthy of remark, that both sides do not have the same degree of inclination: on one side we generally find an abrupt escarpment, and on the other a gradual slope; so that the general profile of any range, taken across the line of its direction, would present the figure of a ridge-like mass or a series of wedge-like masses; a circumstance occasioned, in great measure, by peculiarities of internal structure. It is a rare thing, moreover, for mountains or hills to form isolated and unconnected masses; but, as already remarked, they occur in ranges or chains, having a definite direction, a considerable length, and a narrower, but still considerable breadth. Smaller spurs or branches are often thrown off into the surrounding country, which again may have their minor branches connected with them, the whole forming a regular and continuous system of valleys.

* Burr's Practical Geology.

CHAPTER V.

ELEMENTARY FACTS AND PRINCIPLES OF GEOLOGY.

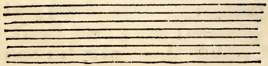
Our Knowledge of the Internal Structure of the Earth very Limited.—Variety of Minerals and Rocks, arranged in a determinate Order.—Advantages of Geological Knowledge.—Division of Rocks: Stratified, Unstratified, Parallel, Inclined, Cropping out, Dip, Thickness, Outliers, Escarpment, Faults, Mineral Veins, Rock Dike, Clay Dike, Formations.—Illustrations.—How to Observe.—Valleys of Denudation, &c.

Having considered the properties of matter, the chemical and mineralogical constitution of the earth's surface, and some points connected with its physical geography, we are now prepared to contemplate those general truths, obtained by observation and experiment, concerning the arrangement of these materials, so far as they may be open to our inspection. We at once, however, perceive that our investigation must necessarily be confined to a comparatively small portion of the mass of the earth, namely, its superficial external crust, which the efforts of man have hitherto failed to penetrate to a greater depth than about 3000 feet. To this we may add the elevation of the highest mountains, and then we find our direct knowledge is confined within the limits of about one eight hundredth part of the earth's semi-diameter; a perpendicular distance varying from five to eight or ten miles; bearing a proportion to the mass of the earth less than that of a thin coat of varnish to an artificial globe of two feet diameter. One of the first things which strikes our observation, as we begin to notice the materials of which this crust is composed, is, that they do not form a simple homogeneous mass, consisting of one substance only, but that there are various kinds of substances, such as soil, sands, gravels, clays, limestones, slates, granite, &c., mingled together, perhaps, in apparent confusion, but still presenting appearances which often interest even the most ignorant observer. How interesting is it to find, on more extended examination, that these apparently confused masses are arranged in a regular order of succession, and that a slight acquaintance with geological facts and principles furnishes a clew to unravel, as it were, the intricate web of a world's formation! What advantage, too, does the geologist possess over those whose observation is not guided by the principles of science. He alone knows where we may expect to find valuable minerals, such as coal, iron, salt, gold, silver, lead, &c.; and millions of dollars might have been saved in searching for these hidden treasures had those engaged in the pursuit been acquainted with the merest elements of the science.

Rocks have been divided into *stratified* and *unstratified*. Stratified rocks are those which are divided into beds parallel to each other, or which, though not parallel, are arranged in separate layers. Various disturbing causes may have destroyed the parallelism of these beds; still the term is retained, and the beds are called strata. Indeed, it is a very rare thing for the layers to be perfectly parallel or horizontal, as the disturbing forces have deranged their position, and thrown some above, while others remain depressed below the general level.

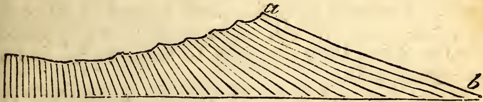
Strata are said to be *horizontal* when they have no inclination with the horizon, thus:

Fig. 9.



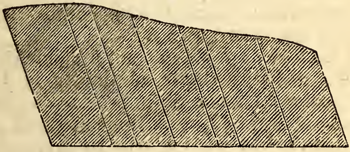
When they are not horizontal, they are said to *dip*, and sometimes they stand vertically upon their edges.

Fig. 10.



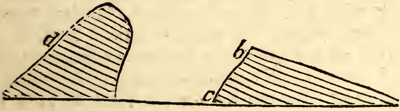
When strata protrude above the surface of the ground, as at *a*, they are said to *crop out*, and the angle at which they incline below the horizon is their *dip*; the *thickness*, of course, is the perpendicular distance between their upper and under surface. Some rocks, particularly slates, are subdivided by numerous vertical joints, dividing the whole mass into cubical or rhomboidal masses, as in the following cut:

Fig. 11.



Outliers are strata detached from the main mass of the bed to which they belong, as in the following cut:

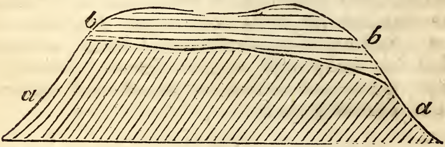
Fig. 12.



The nature of the rock, and the thickness and direction of the strata, prove that they are the same formation, and that the intervening mass has been removed by some local causes. When strata terminate abruptly, they are said to end in an *escarpment*, as at *b c*. When rocks present nearly perpendicular faces, they are said to form *mural* or wall-like precipices.

Strata are said to be *conformable* when their general planes are parallel, as *a a*, figure 13 : and *unconformable* when a series of upper strata rest on a

Fig. 13.



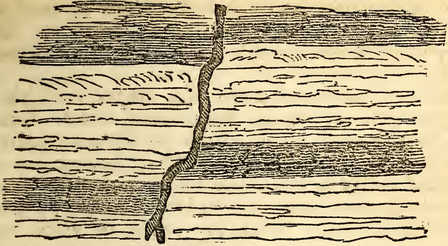
lower formation, without any conformity to the position of the latter, as *b b*.*

What is called a *fault* is such a dislocation of the strata that not only their continuity is destroyed, but the series of beds, on one or both sides of the fractures, are forced out of their original positions. This is applicable particularly to minerals, which are generally found in veins, such as lead, copper, and sometimes coal. In such cases the bed may be formed again, either above or below its original level.

In the following figure the dark strata represent a bed of coal cut off by the vein running vertically. The matter filling the vein is called a *dike*. If we suppose this to have been projected from beneath in a liquid form, it will account for the dislocation of the bed of coal. In such cases we are to look for the

* Comstock's Geology.

Fig. 14.



bed above the lowermost strata. In other words, if the dike makes an acute angle with the upper surface of the coal-vein, the strata are elevated on that side; while, if the angle is obtuse, they are thrown down.

The extent of vertical displacement occasioned by faults varies from a few inches or feet to thousands of feet. It is not uncommon in coal-fields to find the strata raised on one side of the dike to the extent of 5 or 600 feet. There are scarcely any phenomena in geology which prove more conclusively the application of a powerful internal force than the displacements under consideration. Sometimes they extend from 20 to 40 miles in length; and all the rocks which have been disturbed by any fault have experienced on one side the same movement and to the same extent, excepting only those portions which have been subjected to violent pressure. It has been remarked, that mineral veins are not otherwise different from faults than by reason of the fissures which these have opened in the rocks being filled with spongy and metallic matters. This filling of a fissure constitutes a *mineral vein;* a similar fissure, filled by basaltic or other rocks, would be called a *rock dike*, if occupied by clay and soft materials, a *clay dike*. How these fissures came to be filled by such substances will be a subject of inquiry hereafter. They vary in thickness from a few inches to hundreds of feet.

When a series of strata of a similar rock are arranged with occasional intervening strata of rocks of another kind, which recur in different parts of the series, they are regarded as having been all formed nearly at the same epoch and under similar circumstances; and such beds are called by geologists *formations*. Thus the strata of shale, sandstone, and ironstone that accompany beds of coal, are called the *coal formation*. Strata of different kinds, in which a gradation is observed into each other, and which contain similar species of organic remains, also constitute a *geological formation*. The chalk with flints, the lower chalk without flints, the chalk marl, and the green sand under the chalk, are regarded as members of what is denominated the *chalk formation*.* There is one circumstance of frequent occurrence which is apt to confound the young geologist, and that is, in travelling in mountainous districts, after passing over a certain series of rocks, he again meets with them in a contrary order. How this is accounted for figure 15 will help to explain.

Fig. 15.

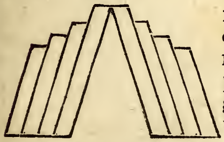
C c are parts of the lowest stratified rocks, *a a* of the highest Now suppose them to be lying in a

* Bakewell's Geology.

horizontal position, conformably upon each other, and a force should be exerted from beneath, in a direction perpendicular to their strata, sufficiently strong to eject the central mass T, is it not plain that, as they are elevated, the broken edges of the several strata will be piled up against the ejected mass? To illustrate this still farther: Suppose, for example, we lay a double series of books on each other in a horizontal position, thus, and then elevate

Fig. 16.

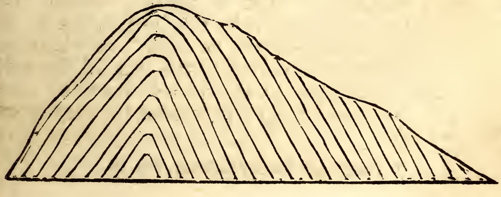
Fig. 17.



them by a force placed beneath the line of junction, the edges, of course, would be raised up, and book would be piled against book, like the gable end of a roof, thus (figure 17):

We sometimes find rocks elevated in this manner, without discovering any evidence of the cause that produced the change of position. The internal force may not have been sufficiently powerful to raise a mass of rocks to the surface, and yet sufficient to fissure the crust and tilt the rocks into a very elevated position, as in

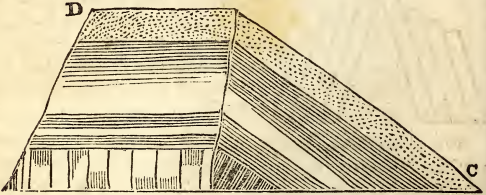
Fig. 18.



We have remarked that rocks are seldom found in a horizontal position: had they been so, the same rock must have been spread over an extensive tract of country, and there would have been great difficulty in obtaining many of those minerals which are now procured at the surface with little or no trouble. This very disturbance, therefore, of the crust of the earth, which at first view seems such an anomaly in creation, proves conclusively the superintending wisdom of the Creator in the adoption and arrangement of those causes best fitted to promote the happiness of man.*

It is quite a common error in geology to mistake the *apparent* for the *real* inclination of the strata. Figure 19 will illustrate this very clearly. It repre-

Fig. 19.

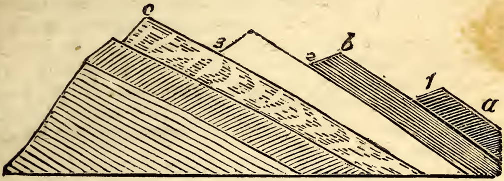


sents a portion of a stratified mountain, of which the strata have a considerable dip to the east. If a section be made in the line of bearing *c d*, the strata will appear to range from north to south without any rise or dip, and would be described, probably, as being horizontal. But if another section be made on the side parallel to the line of dip, as at *c c*, the true inclination will be seen. Any section made in a different direction to the line of dip will cause the inclination to appear less than the true one, and the line of dip will appear to vary from the true dip.

* Higgins.—Family Library, No. 78

Again: a person who first begins to observe geological phenomena is very apt to mistake an *under* for an *upper* stratum. For example, suppose (in figure 20) a hill to be covered with vegetable soil, and

Fig. 20.



a quarry or pit to be made in it near the bottom, as at *a*, and the stone was discovered to be sandstone; if another pit was sunk higher up at *b*, which cut into limestone, it might be supposed, because the limestone is met with at a higher level, that it lies over the sandstone stratum, when it is, in reality, below it. And so at *c*, at the top of the hill, he might suppose that the *slate* which crops out on the summit was above both the others, when, in fact, it is the *lowest* of the three in the order of position, though the highest in point of elevation.

We often read in geological works of *valleys of denudation;* these may be explained by the following figure.

Fig. 21.

Here we perceive that several tracts of the upper strata are wanting between A and B (fig. 21), and that the lower strata have been laid bare either by the action of water or some convulsion, which has torn off and carried away the strata by which they were once covered.* This, therefore, is called a *denudation;* and such instances are of frequent occurrence.

When valleys take the same direction as that of a range of mountains, they are called *longitudinal valleys;* when they cut through a range of mountains, they are called *transversal valleys;* in which case the strata on each side are generally the same. Small valleys, which open into a larger valley nearly at right angles to it, are called *lateral valleys.* Sometimes a valley is formed by the bending of the strata, thus:

Fig. 22.

Bakewell remarks, that the beds or strata of very lofty mountains are generally much inclined, and are sometimes nearly vertical. Among these highly-inclined beds we not unfrequently find beds of limestone, containing marine shells which must have been originally deposited at the bottom of the ocean. In some instances we meet with vertical strata, containing rounded pebbles and water-worn fragments of other rocks. These must also have been originally deposited on a surface nearly horizontal. We are therefore certain that the present vertical position of these strata is not their original one; and we hence also learn, that all the strata associated with them in the same mountain, and having the same inclination, were raised together. We have farther proof that, before the epoch when this great revolution was effected, all these beds were covered by seas then existing, and that it was

* Bakewell's Geology.

under the ocean that the change of position took place. No person who reflects on the appearances presented in a mountainous district can believe that the broken and elevated beds, the peaked summits, the impending cliffs, and the immense fragments of rocks scattered in the valleys and adjacent countries, were originally created and placed as we now observe them.

CHAPTER VI.

CLASSIFICATION OF ROCKS.

Classification: Primary, Secondary, Transition, Tertiary.—Classification of Conybeare and Philips.—Of De la Beche.—Primitive Rocks described.—Mr. Lyell's Views.—Hypogene.—Division of Primary Rocks: Granite, Syenite, Felspathic, &c.—Professor Hitchcock's account of Granite.—Gneiss.—Mica Slate.—Hornblende Rock.—Crystalline Limestone.—Quartz Rock.

We have already stated that the principal division of rocks is into *stratified* and *unstratified;* another is into *fossiliferous* and *non-fossiliferous;* indeed, one of the first classifications of rocks was founded on the discovery that some rocks contain organic remains, while others are destitute of them. As the lowest series of rocks with which we are acquainted give no evidence of the existence in them of either vegetable or animal relics, they were very naturally supposed to have been formed before the creation of things that have life, and were therefore called *primary*, or the *primitive class;* while those beds which contain organic remains were called *secondary.* In a short time, however, it was perceived that an intermediate class was necessary to comprise those beds which are formed of the comminuted fragments of the primitive rocks, but which contain few vegetable or animal relics. Such a class, therefore, was adopted, under the name of *intermediate* or *transition* class. Still later, owing to the progress of the science, a *third division* was added, called the *tertiary*. So that all the different rocks and strata that cover the earth's surface are commonly arranged under the following classes:

1. Primary.	4. Tertiary.
2. Transition.	5. Basaltic and Volcanic.
3. Secondary.	6. Diluvial and Alluvial.

As, however, other classifications have been made which are often referred to by geological writers, it will be necessary to become acquainted with them to a certain extent. Conybeare and Philips, in their geology of England and Wales, divide the crust of the earth into five portions, forming the following classes:

1. The *superior*, containing the *tertiary* deposites.
2. The *supermedial*, containing the *chalk*, *green sand*, *Wealden*, *oolitic*, and *red sand* formations.
3. The *medial*, containing the *coal measures*, *carboniferous limestone*, *millstone grit*, and *old red sandstone* formations.
4. The *submedial*, comprising the transition rocks.
5. The *inferior*, containing the primitive rocks.

M. de la Beche, one of the ablest geologists of he present day, has made the following classification of rocks, which has been adopted by many geologists as superior to any other.

1. Stratified Rocks.

Group 1. *Alluvial.*—Peat bogs, sands, coral islands &c.

Group 2. *Diluvial.*—Transported bowlders & blocks, gravels, &c.
" 3. *Supercretaceous.*—Upper and lower fresh-water and marine formations.
" 4. *Cretaceous.*—Chalk, green sand, and Wealden rocks.
" 5. *Oolitic.*—The oolites and lias.
" 6. *Red sandstone.*—Red marble and sandstone, magnesian limestone, and red conglomerates.
" 7. *Carboniferous.*—Coal measures, carboniferous limestone, and old red sandstone.
" 8. *Graywacke.*—Graywacke and graywacke slates.
" 9. *Lowest fossiliferous.* — Argillaceous and other slates.
" 10. *Non-fossiliferous stratified.*—Mica slate, gneiss, &c.

UNSTRATIFIED ROCKS.

" 1. *Volcanic.*—Lavas, &c.
" 2. *Trappean.*—Greenstone, basalt, porphyry, amygdaloid, &c.
" 3. *Serpentine.*—Diallage rock and serpentine.
" 4. *Granitic.*—Syenite, granite, &c.

Primary or *primitive rocks* are supposed by geologists to constitute the foundation on which rocks of all the other classes are laid; and, as we have stated, were so called because they contain no fossil remains of animals or vegetables, nor any fragments of other rocks imbedded in them. These rocks are, for the most part, extremely hard, and the minerals of which they are composed are often more or less crystallized. They occur in immense masses or beds, forming not only the lowest parts of the earth's surface with which we are acquainted, but also, piercing through the incumbent rocks, they form the summits of the highest mountains. When, therefore, we see a mountain bounded by a plain, we are not to suppose that the strata of which it is formed terminates at its base, but rather that they dip under the other rocks at angles more or less inclined, penetrating far into the interior of the earth, and often rising again in remote districts.* It is proper, perhaps, here to remark, that Mr. Lyell, the distinguished President of the London Geological Society, in his Elements of Geology, objects to the word *primitive*, on the ground that it is not true that all granites and rocks called primitive were first formed, and the aqueous and volcanic rocks superimposed. He thinks that granite has originated at different epochs, some antecedent, others subsequent to the origin of many fossiliferous strata, and, by the agency of internal heat, ejected in the form of veins or dikes through the superincumbent rocks, perhaps changing the very rock containing fossils into crystalline granite or gneiss. He therefore proposes the term *hypogene*, from the Greek words signifying "under" and "to be born," signifying that such rocks are formed beneath the others, and have not assumed their present form and structure at the surface. He also calls such rocks *Plutonic*, because he believes they could not have acquired their crystalline structure unless they had been modified by the agency of heat under great pressure in the depths of the earth.

De la Beche also remarks, "that in the earlier days of geology, granite was considered the fundamental rock on which all others were accumulated; but this opinion, like many others, has now given way before facts: for we have examples of granite resting upon stratified and fossiliferous rocks of no very great comparative antiquity. It must, however, be confessed, that granite appears sometimes to alternate in considerable thickness with the inferior stratified rocks, and that the separation of it from gneiss

* Bakewell's Geology.

is very ambiguous. Primitive rocks occur either as protruded masses, as overlapping massos, resulting from the spread of matter after ejection, or as vein-stones, filling fissures, apparently consequent on some violence to which the strata have been subjected."

Primary rocks are chiefly composed of the hard minerals, *quartz*, *feldspar*, and *hornblende*; mica and talc are disseminated in smaller proportions, and limestone and serpentine occur in beds or masses, but less frequently than the above-named minerals.

CLASS I.

Primary Rocks.

1. Granite. 2. Gneiss. 3. Mica Slate.

Subordinate Rocks which occur among Primary.

1. Hornblende Rock.	3. Crystalline Limestone.
2. Serpentine.	4. Quartz Rock.

Some of these subordinate rocks occur also among transition rocks. Bakewell justly remarks, that granite, gneiss, and mica slate might with propriety be regarded as belonging to one formation, as they are essentially composed of the same minerals, varying in different proportions, and, accordingly, are rather modes of the same rock than different species. We often, indeed, see them passing into each other, as one of their constituent minerals becomes more or less abundant.

Granite.

Granite is a compound rock, composed of *quartz*, *feldspar*, and *mica*, arranged in various proportions, and varying accordingly the aspect of the mineral. The crystals of each may be large or small; in one portion of the rock equally mixed; in another, unequally blended; so that we often find the quartz or feldspar predominating. Indeed, feldspar forms by far the largest part of granite.

Fig. 23.

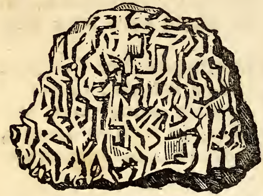


Figure 23 represents a section of graphic granite transverse to the laminæ.

Fig. 24.

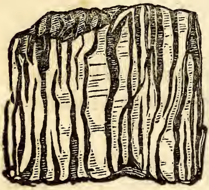
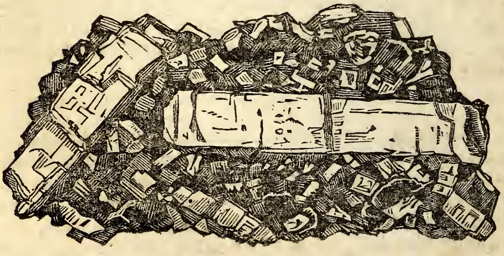


Figure 24 represents a section of graphic granite parallel to the laminæ.

Figure 25 represents *Porphyritic granite*, containing large crystals of feldspar scattered through the

Fig. 25.



base, which contains black specks of mica. The remainder of the mass is quartz.

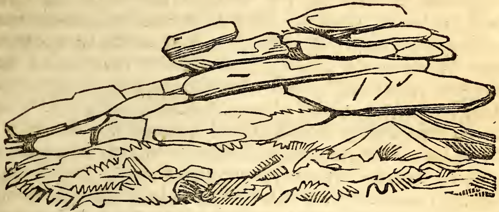
When *hornblende* is the substitute for mica, the rock is called *syenite*, from the celebrated ancient quarries in Syene, in Egypt. This often passes into the syenitic greenstone, a rock of the trap family. A compound of quartz, feldspar, mica, and hornblende is called *syenitic granite*. *Talcose granite* is a mixture of feldspar, quartz, and talc, called by the French *protogine*. This produces, by its decomposition, the China or porcelain clay, more than 12,000 tons of which are annually exported from Cornwall, England, for the potteries.* *Felspathic granite* is that in which the feldspar is the principal ingredient, and the quartz, and particularly the mica, very rare. This kind of rock is frequently nearly white; feldspar being generally white, though it is sometimes flesh or rose-coloured. All these granites pass into certain kinds of trap, which lends great plausibility to the prevailing theory, that the granites are of igneous origin. It has been shown that the minerals which compose the granitic as well as volcanic rocks, consist almost exclusively of seven elements, namely, silica, alumina, magnesia, lime, soda, potash, and iron; and these may exist in about the same proportions in a porous lava, a basalt, or a crystalline granite. "The ordinary granite of Aberdeenshire," says Dr. MacCulloch, "is the usual ternary compound of quartz, feldspar, and mica; but sometimes hornblende is substituted for the mica. But in many places a variety occurs which is composed simply of feldspar and hornblende; and in examining more minutely this duplicate compound, it is observed in some places to assume a fine grain, and at length to become undistinguishable from the greenstones of the trap family. It also passes in the same uninterrupted man-

* Boase on Primary Geology.

ner into a basalt, and at last into a soft clay stone, with a schistose (slaty) tendency on exposure, in no respect differing from those of the trap islands of the Western coast." The same writer mentions that in Shetland, a granite composed of hornblende, mica, feldspar, and quartz, passes in an equally perfect manner into basalt.

Granite occurs in masses of vast thickness, which are commonly divided by fissures into blocks that approach to a rhomboidal shape; and sometimes, in mountains, we see it assume a columnar structure. Granite forms sometimes extensive ranges of mountains, whose aspect varies extremely. Where the beds are nearly horizontal, or where the granite is soft and disintegrating, the summits are rounded, heavy, and unpicturesque; but where it is hard, and the beds are nearly vertical and have a laminar structure, it forms lofty peaks, that shoot their needle-shaped spires into the sky; as in the vicinity of Mont Blanc, where the Aiguille de Dree rises above its base nearly to a point in one solid shaft more than 4000 feet high. In the Andes the granite rises to an elevation of about 12,000 feet; the summits of which are covered by basalt, porphyry, and lava ejected from the numerous volcanoes, which now exist or formerly existed among them. The summit of Chimborazo, which is 21,440 feet in height, is a vast cone or crater composed of volcanic productions covered by snow. "The general arrangement of the Andes," says Humboldt, "consists of granite, gneiss, mica, and clay slate, on which are frequently laid porphyry and basalt, arranged in the form of regular and immense columns, which strike the eye of the traveller like the ruins of enormous castles lifted into the sky." Where hills are formed of granite, they are, for the most part, of a peculiar rounded form, wholly clad with a scanty vegetation. The surface of the rock is generally in a crumbling state, and the hills are often surmounted by piles of stones like the remains of a stratified mass, as in the annexed figure.

Fig. 26.



Granite sometimes forms veins shooting up into the superincumbent rocks. This is a geological fact of considerable importance, as it seems to indicate either that the granite has been in a state of fusion, the heat of which has softened and rent the upper rocks, and forced up the granite in a melted state into the fissures, or else that the granite and the rock resting immediately upon it were both in a fluid state at the same time, and, therefore, are contemporaneous. Professor Hitchcock, in his Report on the Geology of Massachusetts, remarks, that "the veins of granite in Massachusetts penetrate only the older rocks, the clay slate being the latest in which they are found. All the older stratified rocks abound in them, though in quartz rock I have rarely met with any. In gneiss they are very common; in talcose slate very rare; in hornblende slate not common; in micaceous limestone sometimes met with; in serpentine I have never found one. In granite and syenite they are very abundant, and almost always the ingredients are much coarser than the granite or syenite that contains them." "In a large majority of cases, the intrusion of granite veins seems to have produced very little disturbance in the rocks containing them. They would seem to have been open fissures, filled by the injection of granitic matter, without materiall affecting the walls except to unite with them chemically." After enumerating several instances where granite is found protruding through the superincumbent rocks, Prof. H. proceeds to sum up his reasons for believing this rock to be of igneous origin; which, although we purposely design in the present work to abstain from theoretical geology, are yet so conclusive as to merit particular mention. These are, 1. The inclined position of the older stratified rocks: 2. The manner in which it is intruded among the stratified rocks: 3. The mechanical effects which it appears to have exerted upon the stratified rocks in its immediate vicinity: 4. Its mechanical effects upon the surrounding strata: 5. Its crystalline structure, and the numerous crystallizations of other substances that have taken place in it.

Gneiss.

Gneiss is composed of the same minerals as granite, namely, *quartz*, *feldspar*, and *mica*, arranged in distinct layers; indeed, it may be called a *stratified granite*. Granite frequently passes into gneiss by an almost imperceptible gradation; where the quantity of feldspar decreases, and the crystals or grains become smaller, if the mica increases in quantity and is arranged in layers, the rock loses the massive structure and becomes slaty, we have then a true gneiss. But if the reverse of this happen, the quantity of feldspar increases and the mica diminishes, the rock loses the slaty structure and becomes massive, and we have granite again. Gneiss rock contains beds of crystalline limestone and of hornblende rock; also most of the metallic ores, garnet, epidote, &c. The declivities of granite mountains are often covered by rocks of gneiss; where it forms mountains, they are not steep and broken as those of granite, and the summits are for the most part rounded.

Fig. 27.

Fragment of gneiss. Section at right angles to planes of stratification.

Gneiss, like granite, often contains hornblende; the only difference between them consists in the stratified and slaty structure of the gneiss.

Mica Slate.

Gneiss becomes mica slate when the mica becomes abundant and the other ingredients small. Indeed, mica slate is essentially composed of mica and quartz intimately combined, the feldspar either being in small quantity, or absent, or occurring in irregular masses. The colour of mica slate is generally a silvery or pearly white, inclining to a blueish gray or a light green; sometimes it is nearly black. It has a slaty structure, like gneiss, and is often waved and contorted, and divided by thin laminæ of quartz. It sometimes contains beds and laminæ of crystalline limestone, or is intermixed with serpentine. It also contains beds and veins of metallic ores. It is not unusual to find granite passing into gneiss, gneiss into mica slate, and mica slate into clay slate, all in the same neighbourhood. *Talcose and chlorite slate* appear to be different modifications of the same mineral substances; in the former, the structure is laminated, and has a soapy or unctuous feel; in the latter it is minutely granular; the prevailing colour of both being green. A slight modification converts talcose or chlorite slate into serpentine and soapstone. These slates are often confounded.

We now come to the *subordinate rocks* among the primary, the first of which, in our division, is,

1. *Hornblende Rock.*

In addition to the description already given of this mineral, we may remark, that when it forms the principal part of rocks, the colour is commonly a greenish black. It occurs in beds in granite, gneiss, and mica slate, and occasionally in argillaceous slate. Bakewell states that it passes into serpentine by an increase of magnesia, which forms one of the constituent parts of hornblende. When hornblende and feldspar are coarsely blended, they form greenstone; and when so incorporated as to form an apparently homogeneous mass, they form basalt, or a trap rock which has all the characters of basalt. Professor Hitchcock remarks, that every deposite of hornblende slate that he has examined in Massachusetts is associated either with gneiss, talcose slate, mica slate, or quartz rock; and that he regards them all as belonging to the same geological epochs, and produced by essentially the same causes. This rock has a tendency to divide into rhomboidal masses, and its layers frequently exhibit numerous and complicated contortions. It contains but few interesting minerals, among which are *garnets*, *epidote*, *and sphene*.

Dr. MacCulloch remarks, that "the origin of hornblende slate from clay slate is completely established by the occurrence in Shetland of a mass of the latter substance, alternating with gneiss and approximating to granite. Here these portions which come into contact with the latter become first silicious schist, and ultimately hornblende schist: so that the very same bed which is an interlamination of gneiss and clay slate in one part, is in another the usual alternation of gneiss and hornblende schist. It would appear that the fusion of clay slate, whether primary or secondary, is, under various circumstances, capable of generating either the common trap rocks or the hornblende slates; nor is it, perhaps, difficult to explain, by a more gradual cooling, and, consequently, a slower crystallization, the particular causes which may have determined the latter rather than the former effect."

2. *Crystalline Limestone.*

Crystalline limestone is a common rock, of which statuary marble is a variety. It forms extensive beds in several of the primary rocks, especially mica slate, with which it is often intermixed. It occurs more rarely in granite than in gneiss, and when it is met with it is coarser grained than when found in mica slate or common slate. Crystalline limestone is granular, contains no organic remains, is imperfectly translucent, and usually of a white colour, though sometimes clouded with black, yellow, or red. A bed of this rock extends, with few interruptions, 700 miles in length, beginning in Canada, passing through Vermont, the western part of Massachusetts and Connecticut, thence through New-York, New-Jersey, &c., to Virginia, and is extensively quarried in a great many places, and supplies most of the marbles used in this country.*

3. *Quartz Rock.*

Quartz rock is an aggregate of grains of quartz, which are either in minute crystals, or, in many cases, slightly rounded, occurring in regular strata, associated with gneiss, mica slate, &c., into which it often passes by an imperceptible gradation. Quartz rock sometimes forms high mountains, as Monument Mountain in Stockbridge, Mass., which is more than 1000 feet high; also some of the ranges of the Rocky Mountains.

* Lieut. Mather's Geology.

CHAPTER VII.

TRANSITION AND SECONDARY ROCKS.

Transition Rocks.—How Divided.—Slate.—Hornstone.—Whetstones.—Hones.—How Slate is Formed.—Its Cleavage.—Transition Limestone.—Graywacke.—Old Red Sandstone.—Claystone.

We now come to consider the next division of rocks, called *transition* or *intermediate*, because they lie between the primary and secondary, partaking, in some respect, the character of both. It is in some of the rocks of this class that we begin first to discover the fossil remains of animals and vegetables, and they may therefore, as Bakewell remarks, be regarded as the most ancient records of organic existence on our globe.

The rocks generally described as belonging to this class are the following, viz.:

1. Slate (Argillaceous).
2. Transition or Mountain Limestone.
3. Graywacke.

1. *Slate.*

We have already described slate* as one of the simple minerals. We may farther remark, that it abounds in most hilly and mountainous countries, resting either on granite, gneiss, or mica slate. Where it is found resting immediately on the primary rocks, it has a more shining lustre, and partakes more of the crystalline quality of mica slate. As it recedes from the primary rocks, it becomes

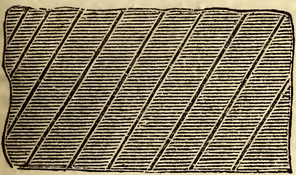
* Where the word slate is used alone, we mean by it argillaceous or clay slate.

more earthy in its texture. It forms beds of various degrees of thickness, and sometimes lofty and serrated mountains, which are covered with verdure on their declivities. Slate rocks vary much in quality even in the same mountain; some being hard and flinty, from containing a quantity of silicious earth; others being soft and shelly, composed chiefly of alumine. Indeed, flinty slate differs from common slate only in containing a larger quantity of silex; and when it loses the slaty character, it is called *hornstone;* and if it contain crystals of feldspar, it is called *hornstone porphyry.* Whetstones and hones are made of talcy slate containing silex; and their excellence is proportioned to the fineness of the silicious particles and their uniform diffusion.

Slate is universally regarded by geologists as a sedimentary rock, formed by the deposition of minute particles of the primary rocks, in the state of mud, which has subsequently been consolidated by heat and pressure. In no other way can we account for the impression of animal and vegetable remains which are often found low down in the rock.

Although slate splits into thin laminæ, yet there are also contained in it certain joints or fissures, traversing it in straight, well-determined lines, causing it to *cleave* in a direction transverse to that of the beds, making with the laminæ an angle usually of from forty to sixty degrees, as seen in figure 28. This affords to the quarryman great aid in extracting blocks of a symmetrical shape. The same vertical joints or cleavings are met with also in limestone, and even in granite. If we make a paste of clay and starch

Fig. 28.



and dry it in the sun, we find that it will split into similar shapes. In like manner, sandstones and other rocks expand by the application of heat, and contract again on cooling; and it is supposed by geologists that large portions of the earth's crust have, in the course of past ages, been subjected again and again to very different degrees of heat and cold, which alterations of temperature have probably caused the phenomenon in question. As such a structure, however, is most conspicuous among rocks of the finest texture, it is supposed by some that it is owing to the influence of crystallization. In proof of this, Scoresby states that the icebergs of Spitzbergen are full of rents, extending perpendicularly downward, dividing them into innumerable columns. On the other side, however, it is stated, that in Saxony, where masses of basalt rest on sandstone, the aqueous rock has, for the distance of several feet from the point of junction, assumed a columnar structure similar to that of the trap; also, that hearthstones, after exposure to the heat of a furnace, without being melted, have become prismatic. The most probable conclusion is, that these fissures are the result of different causes, such as some modification of crystalline action, or simple contraction during consolidation or during a change of temperature. Nearly all the metallic ores have been found in slate, particularly lead and copper.

Carbonaceous matter first begins to appear in the slate rocks, there being none in the primary. Drawing-slate has about 11 per cent. of carbon. This rock is also the oldest that contains any organic remains.

2. *Transition Limestone.*

Transition limestone differs from the primitive in being less crystallized in its structure, more compact and fine grained, more variegated as to colour being white, red, brown, gray, black, or streaked. It occurs in beds alternating with slate, graywacke, and coarse sandstone, and sometimes forms mountain masses. It contains but few petrifactions. This rock abounds in natural caverns, which often seem to have been formed by the agency of water percolating through natural fissures, and in the lapse of ages excavating the softer or more broken parts of the rock. Transition limestone abounds in metals; the principal ores are those of lead and zinc, which commonly occur in veins. It contains also organic remains, such as *encrinites*, *madrepores*, and *corallites*. In England and Wales alone, 553 specimens of organic fossils have been discovered in what is called, by Mr. Murchison and others, the Silurian system, which, though composed in part of limestones, embraces also some varieties of shale and sandstone. Of these, 14 species are *plants*, chiefly ferns, seaweed, and rushes; 87 *Polyparia;* 34 *Crinoidea;* 206 *Conchiferæ;* 64 *Gasteropoda;* 79 *Cephalopoda;* 4 *Annulosa;* 65 *Crustacea;* and some fragments of fishes.

The transition limestone occupies a narrow belt of very great length in the United States; extending through North Carolina, Virginia, Maryland, Pennsylvania, and New-Jersey, it enters the State of New-York in Orange county, thence passes the Hudson at Newburgh, and so up on the east side of the river to Hudson, where it again crosses, or, rather, occupies both banks, and, stretching north, forms the Indian ridge elevation of several hundred feet near Kingston; thence, passing west through Albany and Schoharie counties, extends northwest across the St. Lawrence into Canada.*

3. *Graywacke.*

Graywacke is a coarse slate, containing fragments of other rocks or minerals, varying in size from one inch or more to the smallest grains. When the

* Professor Renwick.

particles become very minute, it passes into common clay-slate; and when the particles are very numerous, and united by a small quantity of cementary matter, it becomes a sandstone or gritstone; and when the fragments are still larger and angular, it is called a *breccia;* when rounded, pudding-stone.

What is called *old red sandstone* by geologists is only a species of graywacke coloured red by oxide of iron. They may often be observed passing into each other, and alternating with mountain limestone; it also passes into claystone by losing its granular structure. The old red sandstone is so called because it is believed to lie lower down, or nearer the primitive rocks than another species, called the *new red sandstone;* but, on the Continent of Europe, the old red and coal formations have been classed as the upper members of the transition series, a method adopted by Dr. Buckland in his late Bridgewater Treatise.

Red sandstone is a rock of considerable importance as a building material. When beds of clay alternate with this rock, the soil is generally very fertile; but where the sandstone alone prevails, the land is mostly barren. A deposite of sandstone extends, with few interruptions, from Vermont, through Massachusetts and Connecticut, down Connecticut River to Middletown, thence to New-Haven, thence to Virginia, a distance of seven hundred miles.*

Sandstone contains impressions of plants and fish, charred wood, and numerous minerals, such as copper and lead, at Simsbury, Conn.; Belleville, Somerville, &c., N. Jersey; and Perkiomen, Penn., &c. In some parts of England the old red sandstone formation is computed to be at least 10,000 feet thick.

* Lieut. Mather.

CHAPTER VIII.

SECONDARY ROCKS.

Carboniferous Group.

Division of Secondary Rocks.—Coal Measures.—Vegetation of Carboniferous Formation.—Lower Secondary Rocks, how Divided.—Millstone Grit—Its Mineral Contents.—Carboniferous Limestone—Its Extent in this Country.—Section of Coal Measures in England.—South Gloucestershire Coal-basin. —Coal-fields of Derbyshire.—Coalbrook Dale.—Coal Measures of North America.

The secondary rocks have been divided into the upper secondary and the lower secondary. The lower secondary are equivalent to the *coal formation*, or, as it is sometimes called, *coal measures*. These are composed of various beds of sandstone, shale or slate, and coal, irregularly interstratified, and in some places intermixed with conglomerates or clay; the whole showing a mechanical origin. Coal measures abound in vegetable remains, and the coal itself is almost universally referred to a vegetable origin, being considered the accumulation of an immense mass of plants. These have been distributed either by the agency of fresh or salt water floods, over areas of greater or less extent, upon a previously deposited surface of sand or argillaceous mud, which afterward has been converted into slate. After the distribution of these vegetables, other sands or mud were accumulated upon them; and this operation, in some places, has been apparently repeated several times.

The vegetables which enter into the composition of coal appear to belong to the lowest order chiefly, such as the vascular cryptogamic plants, like the ferns, equisetaceæ (horsetail), rushes, &c.; and, what is worth remarking, these plants must have attained a magnitude far beyond those of the same class now existing. For example, M. Brougniart observed, in the coal strata of Dortmond, stems of such vegetables more than 40 feet long; and they have been found, in the coal-beds of England, nearly 50 feet in length. These and other facts have led geologists to believe that the vegetation of the carboniferous group was produced in climates at least as warm as those of the tropics; for such is the perfect state of preservation of the plants, the tenderest leaves having sustained no injury, that we cannot believe them to have been wafted from tropical regions.

Mr. Philips remarks (Geology, vol. i., p. 158), that "the organic remains of the coal measures consist of very many races of plants, abundance of zoophyta, multitudes of mollusca, some crustacea, *many fishes*, but, as far as we yet know, neither reptiles, birds, nor mammalia. Many of the plants, indeed by far the greater number, are of terrestrial growth; all the zoophyta, and nearly all the mollusca, crustacea, and fishes, are marine. The excepted mollusca occur among the remains of plants swept down from the land, and the excepted crustacea are those referred to a fresh-water origin. The plants are partly very similar to existing races, as the large group of ferns generally, and partly appear altogether unlike them, as the large-furrowed stems of *sigillaria*, the quincuncially ornamented stigmaria," &c.

The following is a brief summary of the plants:

Equisetaceæ . .	60	species.
Filices	100	"
Lycopodiaceæ	60	"
Phanerogamia mon.	10	"

Coniferæ	. . . .	10 species.
Indeterminate	. .	50 "
		——300 species.

These facts seem to show conclusively that the flora of the epoch of the coal formations was very different from that of the present day, as the vegetable families which are now the most numerous were then wholly wanting, and those which are now comparatively rare were then numerous. Vegetables also, which are now mere herbs, then attained the size of large trees; as, for example, the ferns, which, though they now attain the height of but a few feet at the most, then grew as large as our tallest trees. This, among other facts, has led geologists to believe that the climate of the surface of the earth at that period was excessively hot, and, not only so, but uniform in every latitude, as the fossil remains of the coal formations of every latitude are the same. But, at the present time, every latitude, and, indeed, every different degree of elevation, has its own species of plants.

It is a remarkable circumstance also, that marine remains have rarely been detected in coal-beds, although they abound in carboniferous limestone, which lies below the coal measures; which circumstance, if it does not prove the deposite of coal to have been effected in fresh water, yet shows that there was something which prevented the presence of marine animals. De la Beche states that the Yorkshire coal-beds in England contain the remains of *ammonites* and *pectines*, and that the fossils of the carboniferous limestone and coal measures are detected in the millstone grit; in other words, that there was an alternation of terrestrial with marine remains. The same fact has lately been noticed in Germany.

This accumulation of vegetable matter, at a remote period in the history of the world, for the use of creatures who should afterward exist on its surface, must strike the least inquiring. To this substance England owes, in no small degree, her commercial prosperity, and it is destined to enrich our own country beyond all calculation.

The transition and the lower secondary rocks often present the same external appearance, but they differ in the nature of their fossils; the former containing animal, the latter vegetable remains. An iron ore, called clay ironstone, is generally found in the shale of the coal measures, either in layers or courses of nodules; these, indeed, are said to be of more regular recurrence than the sandstones and shales, which are more or less variable.

The medial, or *lower secondary* order of rocks, is made up of four series:

1. *Millstone Grit and Shale.*
2. *The Coal Measures.*
3. *Carboniferous Limestone.*
4. *Carboniferous Sandstone.*

Millstone grit is composed of angular fragments of quartz and feldspar, held together by a hard argillaceous cement. The *shale* is distinguished from *clay slate* by being an aggregate of minutê particles, instead of being wholly made up of a single mineral species. These rocks alternate with each other without any regular order; they may lie either above or below the coal measures. The stratification of millstone grit is sometimes difficult to detect, on account of the thickness of its beds and its resemblance to some of the rocks not stratified. It contains but few organic remains, and those of a vegetable kind. It however abounds in minerals, such as *galena* (lead), *blende* (zinc), *pyrites* (sulphuret of iron), *copper* (carbonate), *sulphuret of mercury*, *specular iron*, *manganese*, &c., besides *phosphate of lime*, *fluor spar*, *and sulphate of baryta.*

The *carboniferous limestone* is usually compact, but occasionally granular or lamellar. It contains imbedded crystals of calc spar, and sometimes passes into magnesian and argillaceous carbonates of lime. It not only alternates with the lower beds of the coal measures, but also with the upper beds of the surrounding group. It appears in caverns of great extent both in Europe and this country.

This limestone is of various colours, from white, passing through all the shades of gray, to black. It is often coloured and variegated by metallic oxides, yielding some of the most beautiful marbles. In England it forms high mountains, and is therefore called mountain limestone. In this country it occupies a vast extent, extending from Michilimackinac on the north, to Kentucky and still farther south. The lead-mines of Illinois and Missouri are contained in it. It should be noticed that the coal of this formation may be of every quality, from an anthracite containing little or no hydrogen, to that which is richest in bitumen. The same stratum often contains both anthracite and bituminous coal, the former where it lies near the surface of the earth, or is traversed by dikes of trap. As this was thrown up in the form of lava or in a heated state, we thus account for the fact that the coal in the vicinity of trap-rocks contains no bitumen, the volatile matter having been thrown off by the heat.

In order to place before the reader an actual view of the formations in which coal has been found, we shall now present sections of some of them in Europe, which may serve as a kind of guide to explorations in search of this mineral.

GENERAL ARRANGEMENT OF THE CARBONIFEROUS SYSTEM.

1. *The Coal Measures.*

(Beginning at the surface

1. Sandstone.
2. Shale or slate.

3. Ironstone.
4. Coal.
5. Beds of limestone, with fresh water-shells.
(Total thickness 1000 yards.)

2. *The Carboniferous*, or *Mountain Limestone.*

1. Millstone grit, sandstone, shale, and coal.
2 Limestone and flagstone, abounding with plants.
3. Lower limestone, filled with marine remains.
(Total thickness 800 yards.)

Beneath these, though not considered as forming a part of the carboniferous system, is the *old red sandstone*, consisting of,

1. Conglomerates and silicious sandstones, without organic remains.
2. Flagstones, marls, and concretionary limestones; scales of fishes; organic remains rare.
(Total thickness 3500 yards.)

2. *Section of the South Gloucestershire Coal-basin*

(Beginning at the top.)

1. Oxford clay.
2. Great oolite.
3. Inferior oolite.
4. Lias.
5. New red sandstone.
6. Coal, alternating with shale and grit.
7. Millstone grit.
8. Mountain limestone.

3. *Section of the Coal-field of Derbyshire.*

(Beginning at the surface.)

1. Beds of clay (containing fresh-water mussel shells).
2. Shale, argillaceous slate of a soft texture.
3. Layers of ironstones in indurated clay

4. Sandstones of different qualities, often in very thin laminæ.

5. Coal, forming numerous beds or layers in the sandstone.

6. Sandstone, called millstone grit, because used for millstones, containing vegetable remains.

7. Calcareous slate or shale, from 300 to 600 feet thick.

8. Mountain or primitive limestone, the lower strata containing marine animal remains, the upper fresh-water deposites, with terrestrial vegetables.

4. *Coalbrook Dale Coal-bed.*

Dr. Mantell, in his "Wonders of Geology," gives the following account of this coal-field: "It is situated on the east side of the range of transition rocks forming the Wrekin and Wenlock Edge, and the coal strata are superimposed on millstone grit. Beds of ironstone occur, abounding in nodules, with organic remains. This coal-field is remarkable for the dislocated and shortened state of the strata, and the intrusion of volcanic rocks, which do not appear as dikes, as in the fissures of the beds, but rise up in mounds or protuberances. The walls of the fissures are in some instances several yards apart, the intervals being filled with debris. Beds con taining marine shells alternate with others abounding in fresh-water shells and land-plants. The series of strata forming this carboniferous accumulation consists of sandstone, indurated clay, slate clay, and coal. A pit sunk in Madely Colliery, in a depth of 730 feet, passed through 86 beds of alternating quartzose sandstone, clay porphyry, coal, and indurated clay, containing argillaceous ironstone in nodules. The sandstones of Coalbrook Dale are fine grained and micaceous, and some beds are penetrated by *petroleum*, which at Coalport escapes from the surface in a tar-spring; bitumen also occurs in some of the shales. Plants, shells, and crustacea are abundant in the shale, and ironstone nodules, and the remains of insects sometimes occur."

On the Continent of Europe, especially in Central France, the coal deposites rest on granite and other primary rocks, without the intervention of limestones or sandstones. In Poland, the lower beds of the coal measures pass insensibly into the transition rocks upon which they rest. Coal is worked in China and in Van Diemen's Land, where it is associated with the same rocks as in Europe. It is fully ascertained that the coal measures sometimes overlie the millstone grit and shale, and sometimes alternate with the carboniferous limestone; hence *their formation may be of any date between the new and the old red sandstone.* Indeed, coal has been found in both these rocks, but not in beds of sufficient thickness to pay the expense of exploration.

Coal occurs in regular strata, coextensive with the other rocks of the formation, though each coal district has its peculiar series of strata, the arrangement of which differ from every other. Each coal-field also contains generally many beds of coal, separated from each other by strata, often numerous, of other rocks. These beds vary from an inch to many feet in thickness. One bed in the coal-field at Liege is 60 feet thick; another, in Scotland, 56. A thickness of six or eight feet is the most convenient for working; and, if less than 18 inches, it will not defray the expense. In the Leinster coal district Mr. Griffith describes 119 distinct strata, consisting of slate, clay, sandstone, and coal, in which the coal occurs 17 times, in layers of from one to four feet thick. The total thickness of the Derbyshire coal-strata is 1310 yards, in which there are 30 different beds of coal, varying in thickness from six inches to 11 feet, making 26 yards of coal. Making every allowance for excess, Mr. Bakewell thinks that the thickness of the strata may fairly be estimated at 2500 feet.

In Newcastle, England, the coal alternates with the rock measures 32 times. Thus: sandstone, 24 yards; coal, six inches; rocks, 10 yards; coal, eight inches; rocks, 22 yards; coal, six inches; rocks, 15 yards; coal, one foot; and so on, till we have 380 yards of rock and 15 yards of coal, with 32 alternations; there being 32 beds of coal, 62 of sandstone, 17 of limestone, one of trap, and 128 of beds of shale and clay.

Mr. Bakewell has deduced the following results from a large number of facts and observations in relation to the coal formation of England:

1. The series of strata called, collectively, the great coal formation, commonly rests upon or covers marine strata, chiefly the upper transition or mountain limestone.

2. The coal strata, to a vast depth, contain exclusively the remains of terrestrial or of fresh-water plants or minerals; hence it may be inferred that such strata are of fresh-water formation, though some of the lower beds in certain districts contain occasionally an intermixture of marine shells.

3. The coal strata appear generally to have been deposited in tranquil water; a few beds only present indications of having been transported from a distance by violent currents.

4. The coal strata, after their deposition in inland lakes or estuaries, subsided and were submerged in the ocean, and were covered in many parts by marine strata, particularly the magnesian.

5. The faults that dislocate the coal strata were, in some instances, formed before the deposition of the upper marine strata; other faults were formed at a subsequent epoch, after the deposition of the marine strata; but in both cases it may be inferred that the strata were beneath the sea when the dislocation by faults took place.

Coal Measures of North America.

In this country the carboniferous series of rocks is extensively developed, as will be seen in the second part of our Treatise, in which we shall present a sketch of the geology of the United States. According to Dr. Mantell and some of our best geologists, our coal is referable to different geological eras; the most ancient belonging to the transition series; the next to the European carboniferous group; and the third to the brown coal, or tertiary lignite. The anthracite of Pennsylvania is associated with conglomerates, sandstones, and argillaceous slate; the conglomerate being composed of quartz pebbles. In the Valley of the Connecticut, Professor Hitchcock states that bituminous coal is intercalated in a group of strata, which he refers to the new red sandstone. Extensive deposites of anthracite coal are found in Rhode Island, of which Professor Silliman gives an interesting account in the American Journal of Science and Arts.

CHAPTER IX.

UPPER SECONDARY FORMATIONS.

Supermedial Order. (*Cretaceous, Oolitic,* and *Sandstone Groups.—De la Beche.*)

Upper Secondary Rocks: how Divided.—Secondary Rocks of England.—New Red Sandstone.—Oolite.—Green Sand.—Chalk.—Flints

The upper secondary rocks, which we have stated lie above the coal measures, comprise, 1. *The New Red Sandstone*; 2. *Oolitic Rocks*; 3. *Green Sand*;

4. *Chalk.* It is in this formation that we find the bones and entire skeletons of enormous reptiles, but few of the mammiferous land quadrupeds. The secondary rocks abound in marine shells, and fossil vegetables are sometimes found in them, but not abundantly. Secondary strata cover a large portion of the habitable globe, and furnish some of the most fertile districts to the agriculturist. This class of rocks contain neither metallic veins nor metallic beds deserving notice (except iron ores), nor do they furnish any rare species of crystallized minerals. They furnish, however, rock-salt and gypsum, and it is from them that nearly all our salt-springs issue. Some of the rocks in this class yield useful building materials, but the stone is generally soft and perishable. The secondary rocks were called by Werner *floetz* or *flat* rocks, because in the northern parts of Europe they are generally arranged in a horizontal position; but this character being found not to belong to the same class of rocks in other countries, the term has gone out of use.

Section of the Upper Secondary Rocks of England.

Fig. 29. Soil.

1. *Green Sand and Chalk.*
2. *Oolite Formation and Beds of Clay.*
3. *Lias Clay and Lias Limestone.*
4. *Middle and Upper Red Sandstone and Marl, with Rock-salt and Gypsum.*
5. *Lower New Red Sandstone and Magnesian Limestone.*
6. *Upper Transition Rocks and Coal Measures.**

* In the sections above given, we have the strata represented in a perpendicular position, for the sake of convenience, and to fix their relative situation more clearly in the mind of the reader.

A writer in the 7th vol. of the American Quarterly Review thus characterizes the supermedial or secondary order of rocks. "It consists of several formations, each of them containing alternating beds of limestone, sandstone, and clay, and each having fossils peculiar to its several floors. The lower beds of this order contain rock-salt and salt-brine, together with gypsum. These minerals lie in what is called the new red sandstone formation, which resembles the old red sandstone so closely sometimes that it is not easily distinguished from it. The middle beds consist of magnesian limestone in England; in Germany they are called *zechstein*, and rest upon a schist containing copper. It is called copper-slate, and contains fossil fish, plants, and the monitor. The beds which lie between the *zechstein* in Thuringia appear to be the equivalents of the Exeter conglomerate, which in many instances shows a decided trap origin. Indeed, we have reasons for supposing many red earths of this character to be decomposed greenstones. With the termination of the coal measures, a new order of things begins. The disturbing causes which have hitherto dislocated the beds, and thrown them often into high inclinations, seem to have ceased; and the rocks henceforward conform to a general horizontality. The beds of the lias, one of the most interesting formations, appear to have been deposited at periods of great repose.

"The lower ones consist of thin argillaceous limestones, separated by marly partings; the upper beds, which are more than twice as thick, consist of blue marls, indurated marls, and irregular limestones. Some of these are fibrous; and the septaria, or cement stones, are used for hydraulic mortar."

In general, the upper secondary rocks differ from

It must be borne in mind, however, that in all hilly and mountainous countries particularly, the strata are more or less inclined, overlapping each other.

the tertiary group, or those lying above them, not only by their *chemical character*, being chiefly cretaceous (carbonate of lime), but by their *greater compactness;* a *want of conformity in their strata* (the secondary being rarely parallel to those of the superior order), and also, as has been already stated, *by a great difference in their organic remains.* The formations which fall under this group may then briefly be described in the following order in the ascending series:

1. *New Red Sandstone.*	2. *Oolitic.*
3. *Green Sand.*	4. *Cretaceous* or *Chalk.*

The *new red sandstone* is so called to distinguish it from that found among mountain rocks, called *old.* Its prevailing character is silicious, but it often comprises calcareous beds of considerable extent. Bakewell divides this rock into three series, viz., the *upper*, the *middle*, and the *lower* beds. These divisions are often well marked by intervening beds of limestone; where such do not occur, they are so blended as to be undistinguishable. It is the general opinion of geologists, that this rock, together with the conglomerate beds found in it, was formed by the violent disintegration of the older rocks, and particularly of trap rocks, that were protruded at the era of some great convulsion, which broke down a large portion of the ancient crust of the globe, and spread the debris far and wide over the bed of the existing ocean. This appears from the fact that fragments of the older rocks occur in the different beds of this sandstone, and that some of the beds are almost entirely formed of such fragments. This mode of formation is supposed to account for the great diversity both in the nature and thickness of the beds in different districts. Some geologists maintain that the disintegrating causes which broke down part of the ancient rocks, and thus spread abroad their ruins, acted at successive periods of comparatively short duration, succeeded by long intervals of repose, during which the calcareous strata were deposited.

We need not enter upon a description of these three formations of the red sandstone, because their character and limits are not, as yet, very clearly defined. This rock is often variegated in colour and various in its texture. Sometimes it is composed of large pebbles and fragments of other rocks cemented together; and then again it passes into variegated marls. These are more generally of a red colour, and cover the sandstone in beds of considerable thickness, forming a stiff reddish loam, with greenish or yellowish stripes, as in many parts of Virginia. These beds are sometimes 500 feet in thickness, and it is in this red marl that the rock-salt has hitherto been found in England. It also contains beds of gypsum. In Poland, extensive beds of iron ore are found in this marl; 27 furnaces, affording annually 560 quintals of metal. Fossils are rare in this deposite, with the exception of vegetable remains. In Swabia it is rich in both iron and coal. It is now pretty well ascertained that the red marl, as well as the sandstone, have been principally formed by the disintegration of rocks of trap, greenstone, syenite, and granular quartz; the *iron* of the trap rocks communicating the red colour by oxidation.

Bakewell supposes that the argillaceous marls have been principally formed from the trap rocks, and the silicious sandstones from the granular quartz rock. In proof of this, it is stated that the red ground in the vicinity of the different trap rocks in Devonshire is invariably composed of fragments of these rocks, increasing in size as they are situated nearer the original formation. That trap rocks are easily affected by mechanical and chemical agents, and rapidly decomposing in consequence, any one who passes up the Hudson River may be convinced by observing the immense quantity of debris and fragments at the base of the Palisades, which have been precipitated from the mural precipices above; and these fragments are finer in proportion as they are more distant from the main body of the rock.

Professor Hitchcock infers from a variety of facts, that the greenstone or trap rocks in the Valley of the Connecticut began to be thrown up not far from the middle of the epoch of the deposition of the sandstone, and also at intervals during the remainder of the period in which the sandstone formation was advancing to its completion.

The red marl produces, in general, a very fertile soil, owing, doubtless, to a due admixture of silex, alumine, and lime; and it is stated by writers on agriculture, that sheep living in marly* districts have their wool tinged with red.

It has been disputed whether the new red sandstone has ever been found in the United States, and especially whether that in the Valley of the Connecticut River belongs to this group of rocks. But some believe there is no good reason to question the existence of this rock not only on the Connecticut, but in the states of New-York, New-Jersey, Pennsylvania, Alabama, &c., &c.

Professor Hitchcock, in his admirable Report on the Geology of Massachusetts, has shown very conclusively, we think, that the sandstone of the Connecticut Valley corresponds to the new red sandstone of Europe; for which opinion he offers the following satisfactory reasons: 1. The discov-

* Quere: May not the nankeen cotton of China owe its colour to the same cause?

We are aware that this species of cotton has been introduced into our own country (South Carolina), and still retains its characteristic colour when grown here. But it is well known that when a plant has, by the influence of cultivation or local causes, acquired certain *habits*, so to call them, it will retain those marks when transplanted to other localities ery of a vertebral animal several feet long,* imbedded in this rock eighteen feet beneath its surface. 2. The occurrence in it of fossil fish, similar to those obtained from the new red sandstone of Germany. 3. From its containing veins of copper ore, as in England; also the sulphates of barytes and strontia, as in England. 4. From the occurrence in it of bituminous marlite and fetid limestone, as in Germany, and also from its variegated character, causing it to resemble that from Nova Scotia so closely as not to be distinguished from it. Indeed, it corresponds in its appearance to the beds of it in Scotland described by Dr. MacCulloch, who represents them to be sometimes of a conglomerate structure, at others a fine sandstone, and occasionally schistose; and "in composition," he remarks, "the rock is calcareous, argillaceous, or ferruginous, or all together, presenting endless varieties of aspect and colour." The sandstone of the Connecticut Valley contains more or less lime, effervescing with acids, and therefore might properly be called a red *marl.* The limestone associated with it is highly fetid, sometimes bituminous. There is one circumstance, which has been thought conclusive, against the opinion that the rock in question belongs to the new red sandstone; that is, that this formation is deficient in gypsum and rock-salt, which are universally found in the new red sandstones of Europe. But it is not a fact that no gypsum is found in it; as masses of this mineral are occasionally met with, and as the rock has not yet been extensively explored, no one can positively say that it does not contain both gypsum and salt. We believe that it does; at any rate, we should like to set Mr. Disbrow to bore some 800 feet below the bed of the Connecticut, to see what

* No vertebral animal has ever been found below the new red sandstone, except those formerly mentioned in the Stonesfield slate.

he would find. If he should happen to strike a bed of rock-salt, we suppose the friends of the *old red*, would soon come over to the *new*.

Associated with this rock in the Valley of the Connecticut, we find beneath it a red *conglomerate*, composed almost entirely of the ruins of granite and mica slate. This doubtless is a variety of the *old* red sandstone. Above the *new* red we find a conglomerate of a dark reddish-gray colour, composed of fragments of mica slate, talcose slate, chlorite slate, hornblende slate, and slaty quartz rock, with occasional nodules of quartz, feldspar, and granite. This is very coarse, the nobules being sometimes 3 or 4 feet in diameter. We also find a *trap conglomerate*, consisting of a mixture of angular and rounded masses of trap and sandstone, with a cement of the same materials.

We also have *sandstones* of different colours and textures; some of them being composed chiefly of fine silicious sand, with specks of mica, and cemented by red oxide of iron. This is quarried for architectural purposes, at Chatham, Connecticut. And, lastly, we meet with *shales* and *limestones*, including under the former several varieties of argillaceous or clay slate, of a gray, red, and black colour, though the red is the most abundant. When black, it is bituminous. This contains an abundance of impressions of fish and vegetables, and contains nodules of iron ore and iron pyrites, from the decomposition of which it often falls to pieces. Professor Hitchcock remarks, that "if it were possible to doubt that the new red sandstone formation was deposited from water, the surface of some of the layers of this shale would settle the question demonstrably; for it exhibits precisely those gentle undulations which the loamy bottom of every river with a moderate current presents. But such a surface could never have been formed while the layers had that high inclination to the horizon which many of them now present; so that we have here, also, decisive evidence that they have been elevated subsequent to their deposition."

Oolite.

The rocks lying immediately above the new red sandstone are called the *oolitic*. They derive their name from the small rounded globules that are imbedded in them; and as these sometimes resemble the *roes* of fish, the rock is called *roe-stone*. This formation abounds on the Continent of Europe, and particularly in England; although we meet with limestone rocks in this country which have an *oolitic* structure, it is yet in dispute whether they are exactly equivalent to the European oolite, either as respects their relative position or their organic remains. According to Conybeare and Philips, the oolitic group may be divided into *three series*, each of which is composed of three distinct formations, viz., an *oolitic rock*, a *calcareous sandstone*, and a *marl*. The oolite rocks are distinguished as *upper*, *middle*, and *lower*, and occupy, in England, a zone which is nearly 30 miles in average breadth, and extends across the island from Yorkshire on the northeast to Dorsetshire on the southwest. These again are subdivided into several varieties, such as *Portland stone*, *Kimmeridge clay*, *Coral rag*, *Oxford clay*, &c.; and below the whole is situated the formation called *lias*. This term is derived from the provincial pronunciation of the word *layers;* as the strata of lias limestone are generally very regular and flat, and can easily be raised in slabs from the quarry. When the lias beds are fully developed, with their associated beds of clay, they form a mass of stratified limestone and clay several hundred feet in thickness, which rests upon the red marl described in the last chapter. This lias limestone is of a dark gray or yellowish white colour; argillaceous; divided into thin strata of an earthy, marly texture, and consists of from 80 to 90 per cent. of carbonate of lime, combined with bitumen, alumine, and iron. If iron enters largely into the composition of this limestone, it forms a lime when burned, which has the property of setting under water.* The finer kinds of *lias* receive a polish, and are used for lithographic drawings. The lias clay or marl is often much impregnated with bitumen and iron pyrites, and will burn slowly when laid in heaps with fagots and ignited. By this process the sulphur in the pyrites is decomposed, and combines with the oxygen of the atmosphere, and with a portion of the alumine in the shale, and forms *sulphate of alumine* or alum. This variety of shale, when moistened with salt water, ignites spontaneously; and Bakewell states that it is not an unusual thing for cliffs of lias in England to take fire after heavy rains, and continue burning for several months. Lias clay is impregnated with a considerable portion of muriate of soda, and sulphate of magnesia and soda. This formation is particularly distinguished by the number and variety of the organic remains which it contains. Besides an immense variety of fossil fish, with the form of the bodies and scales well preserved, we find imbedded in it the skeletons of enormous animals allied to the order of lizards or saurians. The bones and teeth of reptiles have sometimes been found in the new red sandstone; but in the lias and the strata above it, the bones of saurian animals are so numerous and of such vast size, that the epoch in which these strata were deposited has been called "the age of reptiles." The characteristic fossils of the lias have not hitherto been discovered in this country, and the rock itself is believed to be wanting.

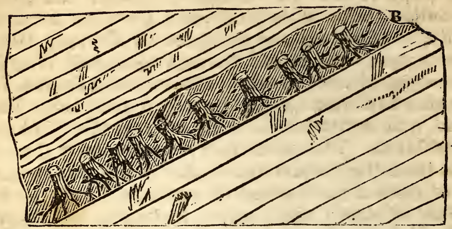
* Mr. Bakewell states that the property of setting under water may be communicated to any kind of lime, by an admixture with burned and pulverized ironstone. This is well worthy of trial.

Above the lias clay we have what is called the *Cheltenham* or *inferior oolite*, which in some places is an arenaceous deposite, sometimes consisting of nearly equal divisions of soft oolite and slightly calcareous sand, with occasional oolitic iron ore: over this, in some places, is a peculiar kind of clay, called *Fuller's earth*, valuable in the useful arts; occasionally it forms beds 150 feet in thickness. Above this comes a *slaty calcareous limestone*, called *Stonesfield slate*, remarkable for its organic remains; and next in order is the *great oolite*, which contains the best and largest beds of building stone, called *Freestone*. Many of the handsomest houses in Bath (England) are built of this stone. As we ascend we next meet with what is called *Forest marble*, containing argillaceous deposites, termed *Bradford clay*. Next we find a coarse, shelly limestone, called *Cornbrash*,* full of fossil remains. The above deposites form what may be called the *second division* of the oolitic series in the ascending order. The *third division* embraces the *Oxford clay*, the *coral rag*, *calcareous sandstone* and *freestone*, and *Kimmeridge clay*. The *upper* and last division of oolite consists of *Portland sand* and *Portland stone*. The latter is of a yellowish white colour, and forms a very fine building stone. The average thickness of the deposites in each of the above divisions is 500 feet, making 1500 feet for the whole; none of which are known to exist in the United States. A great variety of fossil remains are found in the series, especially in the Stonesfield slate, such as those of the *megalosaurus* or *gigantic lizard*, which was forty feet in length and twelve feet high; also of birds, and animals of the *opossum genus*, and of

* This word derives its name from the facility with which it disintegrates and yields to the plough; being, according to a provincial term, *brashy* or breaky enough to enable the plough to prepare the surface where it prevails for wheat, which is always called *corn* in England.

pterodactyles, or flying lizards, varying from the size of a snipe to that of an eagle. Above the oolitic formation there is in England a peculiar local deposite, confined to the counties of Dorset, Hants, Sussex, and Kent, called *Purbeck strata* and *Wealden*, consisting of beds of clay, common sandstone, calciferous sandstone, conglomerated sandstone, limestone, and ironstone, forming an average thickness of 1000 feet. This formation is particularly remarkable, from the circumstance that the fossil remains are of *fresh-water* instead of *marine* origin. Over a surface of some sixty miles in length and twenty in breadth, the limestone, sandstone, clay, and conglomerate contain almost exclusively the remains of fresh-water animals and terrestrial plants, while immediately below we find an abundance of the remains of marine animals. These two formations are separated by a calcareous bed about two feet thick, upon which is spread a stratum of dark clay from two to six inches in thickness, containing fossil specimens of *cycadiæ*, analogous to living species of *cycas*. "Thus," says Bakewell, "at the distance of two feet we find an entire change from marine strata to strata once supporting terrestrial plants; and should any doubt arise respecting the original place and position of these plants, there is, over the lower dirt-bed, a stratum of fresh-water limestone, and upon this a thicker dirt-bed, containing not only the cycadiæ, but stumps of trees from three to seven feet in height, in an erect position, with their roots extending beneath them. Stems of trees are found prostrate upon the same stratum; some of them are from twenty to twenty-five feet in length, and from one to two feet in diameter. The following section of a cliff in Dorset exhibits very clearly proofs of the alternation from marine strata to dry land covered with a forest, and of a subsequent submergence of the dry land under a river or lake which deposited fresh-water limestone.

Fig. 30.



A, Portland Marine Limestone; B, Ancient Forest in the Dirt-Bed; C, Lower Purbeck Beds of fresh-water Limestone.

The *upper series* of the secondary formations consists of *beds of green sand* and *chalk*. In England, France, and Germany, this comprises a formation of great depth, computed to be at least one thousand feet in thickness, and its exclusively marine fossils prove that it was formed beneath the ocean.

The lower part of this group has been usually called the *green sand formation*, because it abounds in green-coloured grains, which give, on analysis, silex, protoxide of iron,* alumine, and potash. This is separated from the chalk above by a bed of grayish blue clay, called *gault*, effervescing strongly, and containing some fossils. The green sand† is thus divided into the *upper green sand*, the *gault*, and the *lower green sand*. The *lower green sand* is very ferruginous, containing beds of sand more indurated towards the bottom with limestone in some localities.

The *upper green sand* is a mass of stratified sands, containing a large portion of the green grains, and

* M. Berthier has analyzed the green particles, and found in every 100 parts 50 of silica, 21 of iron, and the remainder to consist of alumine, potash, and water.

† Prof. Renwick states that *green sand* owes its colour to a *chloritous silicate of iron.*

occasionally green or reddish nodules, which, upon analysis, have yielded phosphates in great proportions. Green sand is variable in its mineral characters, sometimes consisting of loose silicious sand; at others it forms sandstones cemented by calcareous earth; it also abounds in silicious concretions, which vary from an opaque hornstone to flint and chalcedony.

In the United States the green sand forms a belt extending from Sandy Hook to Georgia, and from New-Jersey* to the neighbourhood of the Mandan country.

Chalk.

The upper portion of the cretaceous group consists of, 1. *Chalk Marl;* 2. *The lower Chalk;* 3. *The upper Chalk;* all of which are deficient in the United States.

Chalk is too well known to need a description. It consists chiefly of *carbonate of lime;* has an earthy texture, and is so soft as to yield to the nail. Though generally white, in some parts of England it is red; and in Switzerland it is sometimes highly indurated, resembling white statuary marble. The greatest thickness of the chalk strata in England is from 600 to 800 feet. The upper beds contain numerous nodules, and short, irregular beds of flint; the lower chalk contains fewer flints, and is generally harder than the upper chalk, and is sometimes used for building stones. The flint nodules are generally arranged in pretty regular layers in the chalk; they occur in detached concretions of various shapes and sizes, and, when broken, sometimes are found to contain beautiful crystals of sulphate of strontian.

There has been a good deal of speculation in relation to the origin of flint, some writers maintaining that flint and chalk were capable of undergoing

* Featherstonhaugh.

a mutual transmutation. Flint is nearly a pure silicious earth; and such earth occurs, under different forms, among nearly all the calcareous rocks, in a greater or less proportion.

Thus we find silicious earth intermixed with primitive limestone; we find rock crystals (quartz) imbedded in it; and we have already stated that silicious grains are often mixed with magnesian limestone and the oolites. It is therefore not at all surprising to meet with silicious earth (flint) in chalk. So also, in *lava*, we find nodules of chalcedony; and chalcedony and flint are virtually the same, silica forming much the largest proportion of both. It is also to be recollected that the hardest rocks and stones are permeable to water; and flint, when first taken out of the chalk, is found full of moisture when fractured. Chalk is rarely distinctly stratified. This is supposed to be owing to the softness of the beds, which appear to have yielded to pressure. Chalk-beds often contain magnesia; some of the French chalk contains at least 10 per cent. of this mineral. The organic remains of the chalk formation we have stated to be exclusively marine. With many species of shells and remains of zoophytes, the teeth, scales, and palates of fishes also occur; and the great preservation in which they are found renders it very probable that chalk was deposited in a deep and tranquil sea.

The vegetable remains in chalk are few, and appear to belong to the order of *fuci; lignite*, however, has been found in the lower bed of chalk, near Rochelle, which Brogniart thinks may have been formed of peat.

CHAPTER X.

TERTIARY STRATA. (Superior order, Conybeare.)

(*Supra-cretaceous Group of De la Beche.*)

Tertiary Strata.—What they Include.—Lower Tertiary.—London Clay.—Middle Tertiary.—M. Deshaye's Classification.—Mr. Lyell's Classification.—Eocene.—Miocene.—Pliocene.—Crag.—Sections of the Thames Valley.—Thickness of Tertiary Beds in England.

The tertiary formations comprise all the regular strata of limestone, marl, clay, and sandstone that have been deposited after chalk. Before the labours of Cuvier, these were considered as mere superficial gravels, sands, or clays. The main reason for separating the tertiary from the secondary formation, is the fact that the tertiary beds contain the bones of the higher order of animals, as perfect in their organization as any of the existing species of land quadrupeds. They are also farther remarkable for the frequent alternations of beds containing the remains of marine animals, with other beds that contain exclusively the remains of land-animals, and plants, and fresh-water shells : hence the latter beds were denominated fresh-water formations.

The tertiary strata of England and France have been arranged under four divisions, viz. :

1. Lower Marine Beds. (Plastic clay and London clay.)
2. Lower Fresh-water Beds. (Marl and gypsum.)
3. Upper Marine Formation. (Sand and sandstone.)
4. Upper Fresh-water Formation. (Limestone and silicious millstone.)

This classification of the tertiary group was made by M. Deshayes. It is founded on the fact first particularly noticed by him, that the fossil shells of the oldest strata of the tertiary have much less resemblance to the living species of the neighbouring seas than those of the newest group. In other words, in proportion as the age of a tertiary formation is more modern, so also is the resemblance greater of its fossil shells to the testaceous animals of the present seas. In carrying out the plan of classification on this principle, Mons. D. has endeavoured to determine the proportional number of shells, identical with living species, which belonged to each group.

The result of a comparison of 3000 fossil shells found in the tertiary strata of Paris, with 5000 recent species, is, that in the oldest tertiary deposites, such as those about London and Paris, about three and a half per cent. are identical with recent species; that about seventeen per cent. of the middle tertiary period are identical with recent species; and that the third division embraces from thirty-five to fifty per cent.; and in formations still more modern, as in Sicily, the number of species identical with those now living is from ninety to ninety-five per cent. To these four groups Mr. Lyell has given the names: 1. *Eocene*. 2. *Miocene*. 3. *Older Pliocene*. 4. *Newer Pliocene*. The first is derived from "eos," *dawn*, and "kainos," *recent*, because the fossil shells of this period contain a very small proportion of living species; which may be considered as indicating the *dawn* of the recent testaceous animals.

Miocene is derived from "meion," *less*, and "kainos," *recent*; and *pliocene*, from "pleion," *more*, and "kainos," *recent*; expressing the *more* or *less* near approach which the deposites of these eras, when contrasted with each other, make to the existing species of molluscous animals.

It may assist the memory to notice, that the *mi*ocene contains a *mi*nor proportion, and *pl*iocene a comparative *pl*urality of recent species; and that the *greater number of recent species always implies the more modern origin of the strata.* At present there are about 9000 *species* of recent shells discovered.

The application of this principle of classification to the tertiary formation of the United States is now in a course of successful prosecution by Mr. Conrad, Drs. Morton, Harlan, Dekay, Hildreth, and other able paleontologists: so that, at no distant period, we shall doubtless be able to pronounce with as much certainty in respect to the comparative ages of our different strata, as they now do in France or England.

The *lower tertiary formation* is subdivided into the *London clay* and *the plastic clay;* the latter rests upon the chalk, and it is called plastic because, in France, it is extensively used in pottery, though in the environs of London it is composed of beds of flint and pebbles alternating with sands and clay. This deposite is remarkable for the vegetable fossils and beds of lignite which it contains. In some parts of England it contains beds of imperfect wood-coal; also remains of marine animals, though fresh-water shells are intermixed.

The *London clay* is placed over the plastic clay and sand; and is the great, dark-coloured argillaceous mass upon which the city of London stands. Its beds are often considerably indurated, and of a slaty structure, and vary in thickness from 100 to 400 feet, or more. Although distinct names have been given to these two clays, yet it is believed that there is nothing in their mineral character which warrants this distinction being kept up, or their being considered other than as a series of clays, where the fossils preponderate in the upper part, and the sand and pebbles in the lower. This deposite belongs to the eocene formation of Mr. Lyell; and scarcely any of the fossils contained in it can be identified with existing species.

The *middle tertiary* constitutes the *miocene* formation of Mr. Lyell; and comprehends the lower fresh-water, the upper marine, and the upper fresh-water of the vicinity of Paris. The lower fresh-water contains silicious limestone, with gypsum, and the bones of extinct animals and fresh-water marls. The *upper marine* consists of gypsum marls, sands, and sandstones, and marine marls and limestone. The *upper fresh-water* contains millstone* without shells, and fresh-water marls. The deposites of this formation contain an increased number of recent shells. Indeed, all its shells are analogous to those of fresh water. Being composed of a mixture of calcareous and silicious earths, sometimes intermixed and at other times separated, when the calcareous portion predominates it forms a limestone. This limestone has often a fine grain, and splintery, conchoidal fracture, resembling the transition marble, and receives a fine polish. Some of the *jets d'eau* in the galleries of the Tuilleries are made of this marble. Many of the harder fresh-water limestones rapidly disintegrate when exposed to air and moisture, and, falling to the state of marl, are used as a manure.

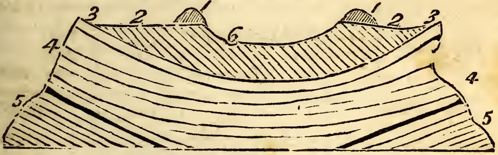
The *upper tertiary*, or the pliocene of Lyell, includes what is called the *crag* in England, which is made up of sand and gravel, chiefly in the counties of Norfolk and Suffolk, the *tertiary hills* of Sicily, and the *sub-Apennine marls*. The *crag* chiefly rests on chalk or London clay. It would seem to have been an ancient beach, where sand, gravel, earth, and red ferruginous sands, containing vast quantities of fossil shells, succeed each other. The

* From this formation the French buhr millstones are obtained. It has a cellular appearance, being full of cavities.

marls consist of various deposites, with sand abounding in fossil shells, of which about forty per cent. belong to existing species. The tertiary beds of Sicily consist of stratified marine deposites of clay, sand, and limestone, at great heights above the sea, and which contain 95 per cent. of existing species.

The following section illustrates the tertiary formations in the valley of the Thames (Eng.).

Fig. 31.



1. Marine sand. 2. London clay. 3. Plastic clay and sand. 4. Chalk. 5. Green sand. 6. River Thames.

Bakewell observes, that from this small section the geological student may form some idea of the devastating effects of mighty inundations, which have swept over the surface of the globe, and carried away considerable portions of the upper beds.

The marine sand, 1 1, which forms isolated caps on several of the hills in the Vale of the Thames, was probably part of one continuous bed, which has been excavated with a portion of the subjacent London clay; such excavations are common phenomena in almost every country.

The following table will exhibit, at one view, the average thickness, in England, of the formations we have now described

		Feet.	
Superior Order.	Pliocene	80	
	Miocene	100	
	Eocene	600	
		——	780

		Feet.	
Supermedial Order.	Chalk	700	
	Green Sand	500	
	Iron Sand	950	
	Upper Oolite	770	
	Middle Oolite	880	
	Lower Oolite	820	
	New Red Sandstone	2100	
			7720
Medial Order.	Millstone Grit	700	
	Coal Measures	1000	
	Carboniferous Limestone	850	
	Do. Sandstone and Graywacke	10,000	
			12,550
Submedial Order.	Transition Limestone	1800	
	Do. Slate	2500	
			4300
Total			24,350

CHAPTER XI.

BASALTIC AND VOLCANIC ROCKS.

Volcanic Formations.—Trap Rocks.—Mineral Composition.—Augite Rocks. — Basalt. — Greenstone. — Trachyte.—Clinkstone.— Porphyry.—Amygdaloid.—Lava.—Scoriæ.—Pumice.—Tuff. — Conglomerates. — Wacke. — Whinstone. — Pitchstone.—Volcano of Kirauea.—Trap Dikes.—Fingal's Cave.—Staffa.—Rocks altered by Dikes.—Faults.—How they cause a Dislocation of Strata.

Volcanic formations constitute some of the most interesting portions of the globe for the geologist to contemplate; for here he sees the effects of those causes still in operation, which, doubtless, have had a powerful influence in consolidating, as well as forming, the earth's surface in the most remote geological epochs.

The rocks which are recognised as belonging to the present class have been called *trap rocks*, from the Swedish word "*trappa*," a stair, because many of them divide into regular forms resembling the steps of stairs. Though this distinction is not universally applicable to rocks of igneous origin, yet every person who has had opportunities of observation must have noticed that many rocks of this class do occur in tabular masses of unequal extent, so as to form a succession of terraces or steps on the sides of hills, as at the Palisades on the Hudson, and West Rock near New-Haven. Bakewell observes that whether the term, in its literal sense, is well chosen as a generic name, may be doubted; but, taken metaphorically, it is extremely appropriate, as these rocks offer a series of gradations or steps, over which the geologist may safely travel in his speculations, from the lava of Ætna to the granite of the Alps.

Mineral composition and texture.—The most common varieties of volcanic rocks are, in regard to their composition, *basalt*, *greenstone*, *syenitic greenstone*, *clinkstone*, *claystone*, and *trachyte;* while those founded chiefly on peculiarities of texture are *porphyry*, *amygdaloid*, *lava*, *scoriæ*, *pumice*, and *tuff:* all these are composed mainly of two minerals, *feldspar* and *hornblende*.

We include *augite* under hornblende, because we think it proved that the same substance may assume the crystalline forms of hornblende or augite indifferently, according to the more or less rapid cooling of the melted mass. It is true that augite often has more lime and less alumine in it than hornblende; but these elements vary; and it is now ascertained by the discoveries of Mitscherlich, of Berlin, that the ingredients of a given species of mineral are not absolutely fixed as to their kind or quality, but one ingredient may, within certain limits, be replaced by an equivalent portion of some analogous ingredient, without affecting the form of the crystal. This law has been called *isomorphism*, from "*isos*," equal, and "*morphe*," form. It is also ascertained that some portions of the materials in a crystal may not be in perfect chemical combination with the rest, as *silex* in crystals of carbonate of lime.

Basalt.—This term is applied to any of the *trap* rocks which have a black, bluish, or leaden-gray colour, and a uniform, compact texture. Indeed, it may be regarded as an intimate mixture of augite feldspar, and iron, to which a mineral of an olive-green colour, called *olivine*, is often superadded in distinct grains or nodular masses. The iron is usually magnetic, and is often accompanied by another metal called *titanium*. Augite or hornblende is the predominant mineral, the feldspar being in much the smallest proportions. Other minerals are also found in basalts; and this may pass into any variety of trap, especially into *greenstone*, *clinkstone* and *wacke*. Basaltic rocks are often covered with a reddish-brown incrustation, owing to the oxygenation of the iron from exposure to the atmosphere.

Greenstone, or *dolerite*, is a granular rock, or one of a granular structure, the constituent parts of which are hornblende and imperfectly crystallized feldspar; the feldspar being more abundant than in basalt, and the grains or crystals of the two minerals more distinct from each other. When the feldspar is red, or the rock contains quartz and is of a highly crystalline character, it is then called *syenitic greenstone*.

Clinkstone.—A trap rock is called clinkstone when the feldspar greatly prevails and the texture becomes nearly compact, causing it to yield a metallic sound when struck. Its prevailing colour is gray, or greenish-gray. When it has a more earthy texture it passes into what is called *claystone*.

Trachyte.—This is a porphyritic rock of a whitish or greenish colour, composed principally of glassy feldspar, with crystals of the same, generally with some hornblende and some iron. It differs from basalt in containing a larger proportion of feldspar than augite, while the reverse is the case with the latter.

Porphyry is a form of rock very characteristic of the volcanic formations. As we have already de scribed it in a former chapter, we need only add, that any rock possessing an earthy or compact base, through which distinct crystals of one or more minerals are scattered, is termed a porphyry. Thus *trachyte* is a porphyry, because it contains distinct crystals of feldspar. If the base be greenstone, basalt, or pitchstone, the rock may be denominated greenstone-porphyry, pitchstone-porphyry, &c.

Amygdaloid.—This compound rock admits of every variety of composition. Indeed, it comprehends any rock in which round or *almond-shaped* nodules of some mineral, such as *agate*, *chalcedony*, *calcareous spar*, or *zeolite*, are scattered through a base of wacke, basalt, greenstone, or other kind of trap. It is derived from the Greek word "*amygdala*," an almond. We can trace the origin of this structure in modern lavas. Small pores or cells are caused by bubbles of steam and gas confined in the melted matter. After or during consolidation, these empty spaces are gradually filled up by matter separating from the mass, infiltered by water permeating the rock. The almond shape of the globules is owing to the bubbles having been sometimes lengthened by the flow of the lava before it finally cooled. Sometimes these pores are empty, as in pumice-stone, giving it a light, spongy appearance, and a capacity of float ing on water.

Lava.—This is an indefinite term, having been applied to all melted matter which flows in streams from volcanic vents. We usually find the upper part *porous* or *scoriaceous*, from its consolidating in the open air ; but, as we descend, the mass becomes more solid and stony, owing to the exclusion of the air and the superincumbent pressure. It is not, however, unusual to find scoriaceous rock at the bottom, owing to the first ejected matter having been spread out in the form of a thin sheet, or, perhaps, from its contact with water in a damp soil.

Lava is often porphyritic, having imbedded in it crystals which have been derived from some older rock, but which, being more infusible than the other ingredients of the same rocks, have been thrown out unmelted.

The term lava is generally confined to such volcanic rocks as have actually *flowed* either in the open air or on the bed of a lake or sea. If the same fluid has not reached the surface, but has been merely injected into fissures below ground, it is called *trap.* Some lavas are *trachytic*, as in the Peak of Teneriffe; some *basaltic*, as in Vesuvius; while others may be a compound of both. In the volcanic districts of Auvergne, scoriaceous lava becomes compact, and at length passes into well-characterized black basalt, with the columnar structure. In some places currents of lava form what is called *obsidian* or volcanic glass. In Christiana, in Norway, trap rock may be seen passing distinctly into true granite.

Scoriæ and *Pumice* are porous rocks, produced by the action of gases on materials melted by volcanic heat. Scoriæ are usually of a reddish brown and black colour, and are the cinders and slags of basaltic or augitic lavas. *Pumice* is a light, spongy, fibrous substance, produced by the action of gases on different kinds of lava, precisely as the porous character of bread is caused by the evolution of carbonic acid gas by fermentation.

Tuff.—*Trap tuff* or *volcanic tuff*, so called, is formed by a mixture of small angular fragments of scoriæ and pumice, together with the dust of the same, which, ejected from the crater, fall in showers, and, mingling with the shells, often become stratified.

We sometimes find such tuffs bound together by a calcareous cement, forming a stone susceptible of a beautiful polish. Some tuffs, or *volcanic grits*, as they have been termed, differ from ordinary sandstones by the angularity of their grains. When the fragments are coarse, the rock is styled a volcanic *breccia*.

Tufaceous conglomerates result from the intermixture of rolled fragments or pebbles of volcanic and other rocks with tuff or tufa. Mr. Lyell remarks, that the extremely compact beds of volcanic materials, interstratified with fossiliferous rocks, may be tuffs, notwithstanding their density. In proof of this, it is stated that the chocolate coloured mud which was poured out for weeks from the crater of Graham's Island, in the Mediterranean, in 1831, must, when intermixed with other materials, have constituted a stone heavier than granite. And, however improbable it may appear, it has been ascertained that each cubic inch of the impalpable powder which has fallen for days through the atmosphere during some modern eruption, has been found to weigh, without being compressed, as much as ordinary trap rocks, which are often identical in mineral composition.

Besides the above, there are other varieties of volcanic rocks, such as *wacke*, which is a soft and earthy variety of trap, having an argillaceous aspect, resembling indurated clay, and exhibiting a shining streak when scratched: also *whinstone*, which is a Scotch provincial term for greenstone and other hard trap rocks: also *pitchstone*, which is a vitreous lava, less glassy than obsidian, a blackish green rock, resembling glass, and having a resinous lustre and appearance of pitch, composed of feldspar and augite, and passes into basalt.

Igneous or volcanic rocks are generally more fusible than others, there being much alkaline matter and lime in their composition, which serves as a flux to the large quantity of silex, which would otherwise prove very difficult of fusion. It is remarkable that, though volcanic rocks abound in silex, they are generally deficient in *quartz*, which is chiefly silex. Most of the volcanic rocks produce a fertile soil by their disintegration. We explain this by supposing that their component ingredients, silica, alumina, lime, potash, iron, and the rest, are in proportions well fitted for vegetation. Thus, in Italy, in the neighbourhood of Mount Vesuvius, the fertility of the soil is astonishingly great, producing the finest grapes in the world.

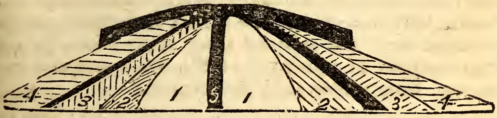
The manner in which volcanic rocks are produced by internal heat, is thus described by Mr. Lyell. "A chasm or fissure first opens in the earth, from which great volumes of steam and other gases are evolved. The explosions are so violent as to hurl up into the air fragments of broken stone, parts of which are shivered into minute atoms. At the same time, melted stone, or *lava*, usually ascends through the chimney or vent by which the gases make their escape. Although extremely heavy, this load is forced up by the expansive power of entangled gaseous fluids, chiefly steam or aqueous vapour, exactly in the same manner as water is made to boil over the edge of a vessel where steam has been generated at the bottom by heat. Large quantities of the lava are also shot up into the air, where it separates into fragments, and acquires a shaggy texture by the sudden enlargement of the included gases, and thus forms *scoriæ*, other portions being reduced to an impalpable powder or dust. The showering down of the various ejected materials round the orifice of eruption gives rise to a conical mound, in which the successive envelopes of sand and scoriæ form layers, dipping on all sides from a central axis. In the mean time, a hollow called a *crater* has been kept open in the middle of the mound by the continued passage upward of steam and other gaseous fluids. The lava sometimes flows over the edge of the crater, and thus thickens and strengthens the sides of the cone; but sometimes it breaks down on one side, and often it flows out from a fissure at the base of the hill."

Of existing volcanoes, none exhibit volcanic action on a more sublime scale than that of *Kirauea*, in Hawaii, in the Pacific Ocean. This whole island, which covers an area of 4000 square miles, is a complete mass of volcanic matter, in different states of decomposition, perforated by innumerable craters, and rising to an altitude of 16,000 feet. "It is, in fact," says Dr. Mantell, "a hollow cone, with numerous vents, over a vast incandescent mass, which doubtless extends beneath the bed of the ocean; the island forming a pyramidal funnel from the furnace beneath to the atmosphere."

Trap Dikes.—Having briefly noticed the mineral characters and composition of volcanic rocks, we are now prepared to consider the manner and position in which they occur in the earth's crust.

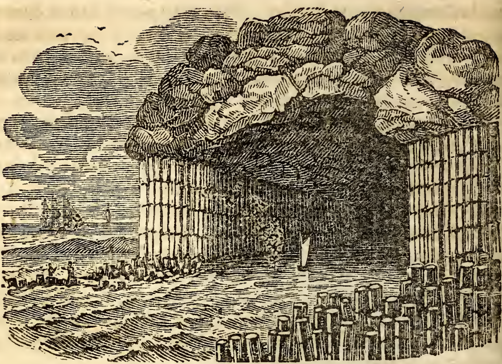
We have already remarked that *basalt* occurs sometimes in veins or dikes, which traverse rocks of all ages, filling up fissures or crevices; and at others, spread over the surface of the strata, or interposed between them, thus:

Fig. 32.



1. Granite. 2. Gneiss. 3. Mica Slate. 4. Argillaceous Slate. 5. Basalt.

Basalt often has a columnar structure, occurring in the form of regular pillars clustered together, as in the following cut, which represents Fingal's Cave, in the island of Staffa, one of the Hebrides.

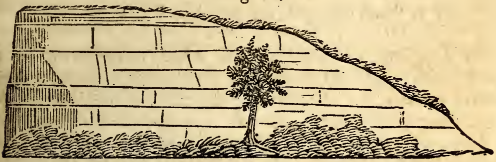


The entrance to this splendid cavern is 50 feet broad and 100 feet high, and its length 250 feet. On each side, as well as at the base, these columns are thickly studded; the whole presenting a singularly rich and varied effect. The basalt of which the columns are composed is of a dark, greenish-black hue, highly coloured by iron. The columns consist generally of five or six sides, though they may range from 3 to 12: and they are made up of numerous joints or separate pieces, united by a thin layer of silicious cement. The whole island of Staffa, which is two miles in circumference, is surrounded on every side by steep cliffs about 70 feet high, formed of clusters* of the same angular columns. Sometimes they are curved.

* Mr. Gregory Watt, in 1804, melted 700 weight of basalt, and kept it in the furnace several days after the fire was reduced. It fused into a dark-coloured vitreous mass with less heat than was necessary to melt pig-iron; as the mass cooled, it changed into a hard, stony substance, and globules appeared; these enlarged till they pressed laterally against each other, and became cemented into regular prisms. It is, therefore, clearly established by this experiment, that the articulated structure

Where we find basalt presenting a perpendicular precipice, as at the Palisades, it is very probable that it has been injected through strata of soft materials, such as shale or tufa, which, being more perishable than the trap, have been washed away by the sea, rivers, or rain, leaving the dike standing out in the form of a precipice, thus:

Fig. 34.



Rocks altered by volcanic dikes.—It might be expected that rocks thrown up in a melted state, through fissures and crevices in other rocks, would produce material alterations in those portions lying nearest to the heated mass, and such we find to be the case. In the north part of Ireland, a bed of chalk 270 feet thick is traversed by dikes of basalt; and at the line of contact, and at several feet from the wall of the dike, the chalk is changed into a dark brown, crystalline rock, the crystals running in flakes, like those of coarse primitive limestone. To this succeeds a still finer-grained variety, and by degrees it becomes compact, with a porcellaneous aspect and a bluish-gray colour, till finally it becomes of a yellowish-white colour, and passes insensibly into unaltered chalk. The flints contained in the indurated part of the chalk are of a yel-

and regular forms of basaltic columns have resulted from the crystalline arrangement of the particles in cooling; and the concavities or sockets have been formed by one set of prisms pressing upon others, and occasioning the upper spheres to sink into those beneath, and thus the different layers have been articulated together. It is not, however, to be inferred that basalt always assumes this shape.

low or deep red colour, and the chalk is highly phosphorescent.

Fig. 35.

1 1 1, *Chalk* changed into marble. 2 2, *Trap dikes.*

In Anglina, a dike 134 feet wide, consisting of a rock composed of feldspar and augite, penetrates strata of shale and argillaceous limestone, which it cuts perpendicularly; these are found changed to a distance of thirty-five feet from the edge of the dike. The shale, as it approaches the trap, becomes gradually more compact, and is most indurated where nearest the junction. Here it becomes a hard porcellaneous jasper. The limestone also loses its earthy texture as it approaches the dike, and becomes granular and crystalline. The altered shale also contains crystals of *garnet* and *analcime*, *while they are found in no other portion of the rock.*

In the county of Antrim, also, chalk with flints is traversed by basaltic dikes, and changed, for a distance of ten feet from the dike, into granular marble.

In the same manner, red sandstone has been converted into hornstone,* and soft slate clay changed into flinty slate.† In Ireland, one of the greenstone dikes of Antrim, on passing through a bed of coal, reduces it to a cinder for the space of nine feet on each side. The same fact has been noticed at Cockfield Fell, in the north of England. Here specimens taken at a distance of thirty yards from the dike resemble common pit-coal; those nearer the

* Geol. Transactions, first series, vol. iii., p. 201.
† Ibid., 205.

dike are like cinders or coke, while those close to it are converted intc a substance resembling soot. In the island of *Sky*, secondary sandstones are converted into solid quartz in several places where they come in contact with veins of trap. Rocks, however, are not always changed when in contact with volcanic dikes, owing perhaps to an original difference in their temperature, or the power of the invaded rocks to conduct heat, or to the quantity of water which they contain. Sometimes, also, the component materials are mixed in such proportions as prepare them readily to enter into chemical union and form new minerals; while in other cases the mass may be more homogeneous, or the proportions less adapted for such union.

In this country the chemical effects of basalt and greenstone upon other rocks are witnessed in many places, though perhaps in a less striking manner than in some other parts of the world. The most obvious changes are observed when limestone is invaded by the trap. At Nahant, near Boston, we find argillaceous slate converted into flinty slate by the influence of greenstone, and in Charlestown, Massachusetts, the same rock* changes clay slate into hornstone. In the Connecticut Valley, at Rocky Hill, a sandstone is changed from a dark colour almost to a white; and from a soft texture to the hardness nearly of flint, and is, moreover, filled with vesicles,† giving it a highly porous character. The same phenomenon can be seen on the east side of Mount Tom,‡ in Northampton. Sandstone also, in contact with the trap, is often found to assume a columnar form. The same fact was observed by Dr. MacCulloch in the hearthstone of a blast furnace.

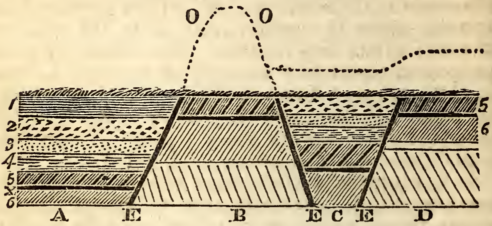
We have briefly alluded to the dislocation of strata by the injection of volcanic matter from beneath.

* Professor Hitchcock. † Professor Webster.
‡ Professor Silliman.

Such phenomena have been called *faults*, and they exist in England and many other parts of Europe to a much greater extent than in this country.

The following cut will represent the manner in which the coal-measures are sometimes elevated:*

Fig. 36.



The preceding cut represents the section of a coal-field in England, several miles in extent, divided into four compartments, A, B, C, D, by faults, which have raised the strata to different depths from the surface. In the part of the field (A), the main body of coal, X, is 900 feet from the surface, and is covered by various strata of sandstone and shale (Nos. 1, 2, 3, &c.). In the part B, the same bed of coal, X, is raised to within 200 feet of the surface, and the strata above are entirely wanting. In the part C, the coal, X, is 700 feet from the surface, and the strata No. 2 is again seen over the coal. In D the coal is brought within 200 feet of the surface, and only a little of the strata 5 is seen. Another thing worthy of notice is, that the surface of the ground above these dislocations is always level, showing that the strata which had been upheaved had been removed by some cause. For example, the part of the coal-field marked B in the above cut has been

* Bakewell's Geology.

elevated 700 feet, and we might therefore expect to see a corresponding elevation of the ground on that side of the fault, as represented by the dotted line O, O, and that the strata would thus form a hill 700 feet high, whereas the ground is level. It is a remarkable fact, that in all coal-fields that we have any knowledge of, an elevation or depression of the strata have no effect whatever in deranging the level surface of the earth.

Every rent or fissure that causes a dislocation of the strata may be called a fault; but fissures filled with metallic ores and crystallized mineral matter are called veins. The faults that intersect coal-fields are sometimes filled with basalt, and are called basaltic dikes; more frequently faults are filled with clay, sandstone, sand, and fragments of stone.

In explaining the cause of this phenomenon, Mr. Bakewell remarks, "That the strata of the coal-formation have been submerged under the ocean, is completely established by the occurrence of marine beds over many of our coal-fields. It is farther proved, that the faults which occur in coal-fields are of different ages; some of them dislocated the coal-strata before the marine strata were deposited over them, for the faults do not disturb nor displace the superincumbent beds: other faults are of a more recent date, and have cut through both the coal-strata and the limestone which covers them.

"Practical miners, as well as geologists, have generally contemplated the removal of the strata upraised by faults as having taken place from the present surface of the land; and have regarded the strata as composed of hard beds of sandstone and shale; and have overlooked the original condition of these strata before they had been raised above the level of the sea, and were indicated by drainage and pressure. In their original state, these beds were chiefly composed of mud and sand, saturated with water, and, therefore, could possess but little adhesion.

"In reference to this inquiry, it is most important to bear in mind the original condition of the strata submerged under the ocean or in deep lakes. We may form some idea of what this condition was, by what we may sometimes observe at the present day in beds of calcareous tufa at the bottom of lakes or rivers recently laid dry. Such beds often yield to the pressure of the finger; but, when exposed to the atmosphere, they harden and form building-stone. Even the strata of sandstone in deep quarries may often be crumbled within the hand;* yet, after long exposure to the air, the same stone yields with difficulty to the chisel of the mason; indeed, the softening power of water is sometimes manifest even in rocks believed to be of igneous origin."

The above view of the subject is undoubtedly a correct one, and will explain all the difficulties hitherto proposed in relation to it. If the basaltic dikes were even protruded after the containing rocks were consolidated, but before they were elevated above the ocean bed, we think it more than probable that such beds, saturated with water, would present but little resistance to the agitation of the ocean, when they were suddenly raised above the lower submarine ground.

We may, therefore, safely conclude, that the disappearance of the strata upraised by faults is owing to the soft and yielding condition† of the submerged

* Much of the marble of Berkshire county, Massachusetts, is flexible when first taken from the quarry, but loses this property by exposure.

† The formation of basaltic dikes is sufficiently explained by what takes place in the vicinity of volcanoes. Before the confined vapour that afterward issues through the crater finds a vent there, the surface of the ground in the vicinity of the volcano is frequently upheaved, and fissures of great extent are made, into which melted lava is sometimes forced, which, on cooling, forms a wall or dike in every respect similar to a basaltic dike. During an eruption of Vesuvius in 1794, a vent of this kind was formed near the bottom of the mountain, 2375 feet in length and 237 in breadth, which became filled with compact

strata, that had never been indurated by drainage, and the violent action of water upon them when they were suddenly broken and forced upward, but were still beneath the surface of the ocean.

One of the largest mineral dikes known to exist is the Cleveland Basalt Dike in England. This has been traced 50 or 60 miles in length, and averages about ten yards in width. There is also another extensive dike near Durham, which throws down the strata on one side of it 160 yards. It is worthy of notice, that as dikes are generally impervious to water, they obstruct its passage along the porous strata, and occasion it to rise: hence it frequently happens that numerous springs make their appearance along the course of a dike, by which it may be detected when there is no other indication of it visible on the surface. Beds of coal are often drained by cutting through a dike, which prevents the escape of the water.

CHAPTER XII.

ALLUVIAL AND DILUVIAL DEPOSITES.

Alluvial Deposites.—Bowlders.—Diluvial.—Mr. Lyell's Theory. —Post Tertiary.—Modern Deposites: Terrestrial, Lacustrine, Fluviatile.

Alluvial beds* consist of the sand and soil brought down by rivers, and deposited in their beds, or scattered upon their banks, or carried into the sea or into lakes, forming deltas at the mouths of riv-

lava. Rents or fissures of some miles in length have been opened on the sides of Ætna.

* The term is derived from "*alluvio*," an inundation; or from "*alluo*," to wash.

ers. They are, of course, made up of the finest and richest portions of every soil over which the water has passed. We accordingly find such a formation distinguished for its fertility, as the banks of the Nile, the Mississippi, the Ohio, and the Connecticut. We find a strip of such deposites along the banks of almost every stream, of greater or less width; also on the shores of lakes and of the ocean. Swamps also consist of alluvial soil, washed thither by rains and brooks, and generally abound in vegetable matter, which might be employed to great advantage as a manure.

Alluvial deposites are sometimes stratified, presenting distinct layers, wavy, horizontal, or oblique, marking successive depositions from water. Mr. Lyell states that "alluvium is strewed alike over inclined and horizontal strata and unstratified rocks; is most abundant in valleys, but also occurs in high platforms, and even in lofty mountains; that of the higher grounds usually differing from that found at lower levels."

It is, however, customary for geological writers to refer beds of gravel, or of stones more or less rounded, that are found in inland districts, as well as the large and detached masses of rock called *bowlders* or *erratic blocks*, to the operation of some great convulsion, by deluges or inundations, more powerful than any causes at present in operation, and to call such deposites *diluvium* or *diluvial deposites*. It is distinguished from *alluvium* by the circumstance that it is much coarser, being made of large pebbles or rounded stones, mixed with sand and fragments of every size, often piled up in rounded hills of considerable height, and under such circumstances as would preclude the possibility of its resulting from existing streams. We find it covering the highest mountains and spread over every kind of rock; in short, so disposed as to prove very conclusively that at some former period a powerful current of water swept over the surface of the earth. Professor Hitchcock remarks, that "in an agricultural point of view it is the least interesting of all our strata; for, of all the soils, it is the most unfriendly to rich vegetation; and as it is spread, in a good measure, over every kind of rock, it often prevents the formation of a good soil from the decomposition of the rock. It is, in general, easily recognised in the most steril places, in the form of low, rounded hills, composed almost entirely of coarse pebbles or cobble stones, and sometimes larger rounded masses of rocks called bowlders, mixed with coarse sand and covered with a stinted vegetation. It was evidently deposited by currents rushing violently over the surface, since only the coarser materials which were driven along were left, while the finer particles were kept suspended by the agitation of the waters. Some varieties of this diluvium may indeed be converted into a soil of tolerable richness, by manuring it abundantly and clearing away the stones. And generally, too, the rains that have fallen on it for thousands of years have conveyed its finer particles to the bottom of the valleys and cavities with which this formation abounds; and these being mixed with much vegetable decayed matter, a soil of good quality is formed. But these fertile spots ought rather to be denominated *alluvium* than *diluvium*."

Mr. Lyell, however, refers *diluvial* as well as *alluvial* deposites to the action of causes now in operation; but he acknowledges that his theory requires "thousands of centuries" to account for the present appearances on the surface of the earth. As such a deposite, however, might have been produced by a general deluge, and as there are no facts in geology which render such a catastrophe improbable, and we are, moreover, expressly told in scripture that such an inundation did happen at the time of "the flood," we think it far more philosophical to attribute the phenomenon in question to such a convulsion.

The alluvial and diluvial formations have been called *post-tertiary* and *modern deposites*, and the chief difference between them and the tertiary deposites is, that in diluvium the sand, pebbles, and clay are confusedly mixed together; whereas, in the tertiary formations, the materials are arranged in regular, and generally in horizontal layers, one above another. Mr. Philips remarks, that it is often extremely difficult to say whether certain aggregations of sand, gravel, and shells are of tertiary date or the productions of later times. Enormous heaps of pebbles and bones lie in particular situations, and are evidently of great antiquity; but whether of the tertiary era or not, requires much care in determining. Certain lacustrine deposites, full of shells, marls, peats, and bones of stags, cannot, by a hasty glance, be known from tertiary strata collected from ancient lakes. But, upon farther and closer scrutiny, geologists have generally agreed that a whole series of deposites, partly marine, partly terrestrial, lacustrine, and fluviatile, has been formed since the date of the truly tertiary strata.

CHAPTER XIII.

AGENTS WHICH DESTROY ROCKS.

Proofs of Changes on the Earth's Surface.—Mechanical Agents which Destroy Rocks: Rains, Torrents, Rivers, Seas.—The Atmosphere.—Influence of the Sea upon the Land: In Europe—In America.

It is quite a prevalent opinion among the common people, that rocks came from the hand of the Creaıor just as we now behold them; but those who have followed us thus far will have seen that such a conclusion must necessarily be erroneous. The remains of animals and vegetables imbedded in the solid rock, thousands of feet beneath the surface, must have led them to conclude that such rocks were formed after the animals and vegetables contained in them had existed; and, in short, that rocks are produced by agents similar to those that are now exerting their influence upon the surface of the globe. But, in order to show how rocks are continually forming at the present time, we must first point out how they are destroyed; for it is by their disintegration and decomposition that materials are furnished for new formations.

Slight observation teaches us that the surface of the earth is everywhere undergoing important changes. The hardest rocks are broken down and decomposed, and a variety of causes are aiding in this work. Although, to the casual observer, the solid inorganic world seems to be steadfast and immovable, yet the earth is constantly taking new states, even beneath his own feet. The effects, it is true, may be gradual or almost imperceptible, but they are none the less certain or efficient. Every stream or river which flows through our country bears along a greater or less proportion of mineral substances; which, being carried into the sea, are again thrown by the waves upon the beach, thus forming a sandy soil like that of New-Jersey or on the eastern side of Long Island.

Rocks suffer disintegration from three different causes, namely: 1. *Mechanical Agents; 2. Chemical Action;* 3. *The Freezing and Thawing of Water.*

I. *Mechanical Agents which Destroy Rocks.*

Water, in its influence upon rocks, may be justly considered as a mechanical agent, although, to a certain extent, it is a chemical one also, as it has the power, especially at a high temperature, of dissolving various mineral substances. The effects of this agent may be considered under four heads, viz., *Rains*, *Torrents*, *Rivers*, and *Seas*.

The influence of rain upon rocks is not sufficiently appreciated. Its amount, of course, will depend upon the nature of the rock; but the hardest is not free from its destructive power. As it beats upon the towering cliff, the rock crumbles away, and the shattered pieces, accumulating at its base, form extensive beds of *detritus*, which are destined to a still finer division, to be eventually carried down to the ocean. By the operation of rains in loosening the soils on the sides of mountains, and rendering the rocks slippery, land-slides often occur, carrying down trees, stones, and earth to the valleys below. Such slides often happen among the mountains of Vermont, Massachusetts, and New-Hampshire; and one at the Notch in the White Hills, in 1826, carried away and destroyed a whole family. This began near the top of the mountain, and bore down, in an impetuous avalanche, the shrubs, forests, soil, stones, and rocks through the space of three miles, so that its desolating track is still plainly visible. Mr. Lyell states that, during a tour in Spain in 1830, he was surprised to see "a district of gently undulating ground in Catalonia, consisting of red and gray sandstone, and in some parts of red marl, almost entirely denuded of herbage, while the roots of the pines, oaks, and some other trees were half exposed, as if the soil had been washed away by a flood." He however explains the appearance by saying, that, being overtaken by a violent thunderstorm, he saw the whole surface, even the highest levels of some flat-topped hills, streaming with mud, while on every declivity the devastation of torrents was terrific. The effects of rain upon beds of clay and sand are too well known to need pointing out more particularly.

Land-slides occur frequently on the north coast of Long Island. In some places they are caused by the sea undermining the cliffs, so that the superincumbent masses crack off at a short distance from their edges, and slide down to a lower level, carrying with them trees and shrubs, and often changing their relative position. These slides are the most numerous where there are beds of clay. A landslide occurred at Troy in January, 1837, caused by a spring of water rendering the clay slippery. The hill was about 227 feet in height, from which a large mass slid off, and, carrying everything before it, swept down a distance of 800 feet, crossing one street, crushing three houses and two barns, and destroying the lives of several persons, who were buried beneath the ruins. The avalanche was accompanied by torrents of water and mud, and the materials now cover a space 200 yards in length by 100 in breadth, and from 10 to 40 feet deep. It is calculated that 200,000 tons of earth were thus transported to a distance of 200 yards.

The *atmosphere* may be considered as a mechanical agent, which has more or less influence in the destruction of rocks, especially when violently agitated, as during storms and tempests. We see hurricanes uprooting the largest trees, throwing rocks from their native beds, and scattering their fragments over the surface.

Action of Running Water.—Lands elevated above the sea attract, in proportion to their volume and density, a larger quantity of that aqueous vapour which the heated atmosphere continually absorbs from the surface of lakes and the ocean. By these means, the higher regions become perpetual reservoirs of water, which descend and irrigate the lower valleys and plains. The water is consequently carried to the higher regions, and is then made to descend by steep declivities towards the sea; so that it acquires superior velocity, and removes a greater quantity of soil than it would do if the rain had been distributed over the plains and mountains equally, in proportion to their relative areas. The rocks, also, in the higher regions are more exposed to atmospheric influences, such as frost, rain, and vapour, and to great alternations* of heat and cold.

Besides, when earthy matter has once been intermixed with running water, a new mechanical power is obtained by the attrition of sand and pebbles, borne along with violence by a storm. Running water, charged with foreign ingredients, being thrown against a rock, excavates it by mechanical force, sapping and undermining till the superincumbent portion is at length precipitated into the stream.

In estimating the transporting power of water, it is necessary to bear in mind that the specific gravity of many rocks is not more than twice that of water, and rarely more than thrice, so that almost all the fragments propelled by a stream have lost from a third to one half of their weight. This may be easily shown by lifting a stone in air, and then in water. It is also well to know that the velocity at the bottom of a running stream of water is everywhere less than in any part above it, and greatest of all at the surface. Accordingly, the superficial particles in the middle of a stream move swifter than those at the sides. This retardation of the lowest and lateral currents is produced by friction; when the velocity is sufficiently great, the soil composing the sides and bottoms gives way. A velocity of three inches per second at the bottom is ascertained to be sufficient to bear up fine clay; six inches per second, fine sand; twelve inches† per second, fine gravel; and three feet per second, stones of the size of an egg.

A few examples will show the immense power

* Lyell's Geology.
† Encyc. Brit., Art. Rivers.

exerted by running water in removing weighty masses of rock. In the year 1829, during a flood in the Highlands of Scotland, a fragment of sandstone 14 feet long, by three feet wide and one foot thick, was carried* about 200 yards down the river.

The stone bridge over the Dee, consisting of immense blocks of granite, which had stood uninjured for 20 years, was also carried away during the same flood; and Mr. Farquharson states that the water forced a mass of 400 or 500 tons of stones, many of them weighing 300 weight, up an inclined plane, rising six feet in eight or ten yards. Mr. Culley also states, that, during a flood among the Cheviot Hills, several thousand tons' weight of gravel and sand were transported by a small rivulet to a great distance to the plain; and that a bridge then building was carried away, some of the arch stones of which, weighing three quarters of a ton, were carried two miles down the stream. A rock also, weighing two tons, was transported by the torrent at the same time to the distance of a quarter of a mile.

The influence of running water in excavating rocks is well known, especially in limestone districts. At Trenton Falls, in this state (N. Y.), there is some of the most romantic and beautiful scenery, produced by a creek having worn a deep notch in secondary limestone to the depth of 100 feet or more, between the perpendicular banks of which it tumbles over several precipices, foaming and roaring; while, over head, the cedars and other evergreens gracefully bend from either bank, forming a beautiful arch in the centre. In like manner, the Genesee River near Rochester, the Connecticut at Bellows Falls and at Haddam, the Shenandoah at the Blue Ridge, and the St. Lawrence from the falls† to near Lake Ontario, all have worn deep

* Lyell.

† Lake Erie is about 330 feet above Lake Ontario, and the distance between them 32 miles. On flowing out of the upper

channels in the rocks which form their beds. One of the most beautiful instances of the effects of running water that we ever witnessed is in the town of Bennington, Vt. A small stream of water, about a rod in width, has worn a perpendicular passage in limestone to the depth of from 40 to 70 or 80 feet; and in some places the opposite walls are so near

lake, the river is almost on a level with its banks, and a rise of ten feet, it is supposed, would lay under water the adjacent flat portion of Canada, as well as New-York. The river is about three quarters of a mile wide, and just above the falls it is a mile wide, 25 feet deep, and has a descent of 50 feet in half a mile. This declivity hurries on the water with astonishing velocity, down what are called "the Rapids," till, at the very verge of the cataract, it is divided by Goat Island into two currents; the one on the Canadian side being about 600 yards wide, and that on the American side 200, while the breadth of the island is 500 yards. The height of the fall is about 170 feet. The rock nearest the surface is transition limestone, deposited in horizontal strata, from 70 to 90 feet thick. Beneath this is shale, of a softer texture, which decays and crumbles away more rapidly, leaving the limestone to project over the stream, as at Table Rock. Between the sheet of water and the rock itself is, as near as we could judge when we visited the place in 1834, about 40 or 50 feet, though it must be acknowledged that the noise, the tremendous blasts of wind and water, and the semi-darkness of the place, are not very favourable to correct observation. The effects of the incessant gusts of wind and water in decomposing the shale, are too obvious to need remark.

Immediately below the falls the river flows along the bottom of a huge trench, which has been cut into the horizontal strata during the lapse of ages. The walls are perfectly perpendicular, and the river cannot be seen till we approach the edge of the precipice. The pool into which the cataract is precipitated is 170 feet deep. During the last 40 years, the latter has worn away about 150 feet of the rock, so that the falls have receded that distance. It is the general opinion, that the falls were once at Queenstown, and that they have gradually retrograded to their present position, about seven miles distant. But it is easy to calculate, that if they have never receded more rapidly than during the last 50 years, it would have taken 10,000 years to have accomplished the distance. At the present rate, it will require 30,000 years for the falls to reach Lake Erie (25 miles distant), so that we need not stand in any particular fear of a deluge for some time to come.

together, that a person may almost leap from one side to the other. The marble is of the whitest and most beautiful description, and, from the action of the water, appears as smooth as if it had been highly polished. On each side of the stream are several "pot-holes," as they are called, of several feet in depth, each containing one or more stones, the constant motion of which by the water doubtless caused these phenomena.

Influence of the sea upon the land.—If we wish to see, upon a large scale, the action of water in wearing down the surface of the earth, we have only to direct our attention to the influence of the sea upon the coasts which bound it. The immense power exerted by the beating waves may be estimated in some degree by a few facts. "The Isle of Stenness," says Dr. Hibbert, "presents a scene of unequalled desolation. In stormy winters, huge blocks of stones are overturned, or are removed from their native beds and hurried up a slight acclivity to a distance almost incredible. In the winter of 1802, a tabular-shaped mass, eight feet two inches by seven feet and five feet one inch thick, was dislodged from its bed and removed to a distance of from 80 to 90 feet. I measured the recent bed from which a block had been carried away the preceding winter (1818), and found it to be 17 1-2 feet by seven feet, the depth two feet eight inches. The removed mass had been borne to a distance of 30 feet, when it was shivered into thirteen or more lesser fragments, some of which were carried 120 feet farther. A block nine feet two inches by six feet and a half, and four feet thick, was hurried up the acclivity to a distance of 150 feet."

Mr. Lyell states, that in building the Bell Rock Lighthouse, off the mouth of the Tay, in Scotland, in 1837, where the water is about 16 feet deep, six large blocks of granite which had been landed on the reef were removed by the force of the sea, and thrown over a rising ledge to the distance of 12 or 15 paces; and an anchor, weighing about 22 cwt., was thrown upon the rock. Mr. Stevensen informs us that drift-stones measuring upward of 30 cubic feet, or more than two tons' weight, have, during storms, been often thrown upon the rock from deep water.

Mr. Lyell farther remarks, that "in the old maps of Yorkshire we find spots, now sandbanks in the sea, marked as the ancient sites of the towns and villages of Auburn, Hartburn, and Hyde." "Of Hyde," says Pennant, "only the tradition is left; and near the village of Hoonsea, a street called Hoonsea Beck has long since been swallowed. Owthorne and its church have also been in great part destroyed, and also the village of Kilnsey; the rate of encroachment at Owthorne being about *four yards a year.*" Upon the coasts of Norfolk, in England, the encroachment of the sea upon the land is rapid and incessant. The whole site of ancient Cromer now forms a part of the German Ocean, and the inhabitants are constantly moving inland to escape the ravages of the sea. In the winter of 1825, a mass was precipitated into the sea which covered twelve acres, the cliffs being 250 feet high. The ancient villages of Shipden, Wimpwell, and Eccles have disappeared on the same coast; several manors and large portions of neighbouring parishes having, piece after piece, been swallowed up: nor has there been any intermission, from time immemorial, in the ravages of the sea along a line of coast twenty miles in length where these places stood. At Durwich, also, the sea has committed extensive ravages. Here two tracts of land, which had been taxed in the eleventh century, were a few years afterward devoured by the sea. We have also an account of the losses, at a subsequent period, of a monastery, then of several churches, then of 400 houses at once, then of the church of

St. Leonard, the high road, town-hall, jail, and many other buildings, with the dates when they perished. In short, this once flourishing city is now but a small, miserable village, the ground a mile and a half wide, on which it stood, having been all washed away by the sea. The village of Aldborough, on the same coast, is known to have been once situated a quarter of a mile east of the present shore. Indeed, where the town formerly stood, the water is twenty-four feet deep. On the coast of Kent there are numerous examples of the loss of land. It is calculated that the Isle of Sheppey, which is now about six miles long by four in breadth, and composed of London clay, will in fifty years be entirely annihilated. The church at Minster, once in the middle of the island, is now situated on the coast near the sea. A little farther east, the town of Reculreec, which, as late as Henry VIII.'s reign, was a mile distant from the ocean, is now partly washed away, and in 1834 an artificial causeway of stones and large wooden piles were driven into the sands to break the force of the waves, in order to save the church from destruction, with which it was threatened.

In the year 1753, a society at Amiens, in France, proposed as a subject of a prize essay the question whether France and England were formerly united. The prize was gained by a young man by the name of Desmarest, who founded his principal arguments on the identity of composition of the cliffs on the opposite sides of the channel; on a sub-marine chain extending from Boulogne to Foulkestone, only fourteen feet under water; and on the identity of the noxious animals in England and France, which could not have been introduced by man. He supposes the isthmus was ruptured by a violent current from the north. On this subject Mr. Lyell remarks, "It will hardly be disputed that the ocean might have effected a breach through the land which, in all probability, once united this country

(England) to the Continent, in the same manner as it now gradually forces a passage through rocks of the same mineral composition, and often many hundred feet high, upon the coast."

In confirmation of this opinion, it is mentioned that Friesland, which was once a part of North Holland, was in the thirteenth century severed from it by the action of the sea, which in about 100 years formed a strait more than half as wide as that which separates England and France.* The encroachments of the sea upon the coast of Sussex (England) have been very great; as within eighty years there are notices of about twenty inroads, in which tracts of land of from 20 to 400 acres in extent were overwhelmed at once. In the town of Brighton, twenty-two houses were destroyed by the sea in the year 1665, and in 1705 all the remainder, 113 in number, which were situated under the cliff, were swept away.

A very extensive fall of ground, occasioned by the undermining of the cliffs, is thus described in Hutchins's History of Dorsetshire. "Early in the morning the road was observed to crack; this continued increasing, and before two o'clock the ground had sunk several feet, and was in one continued motion, but attended with no other noise than what was occasioned by the separation of the roots and branches, and now and then a falling rock. At night it seemed to stop a little, but soon moved again; and, before morning, the ground from the top of the cliff to the water side had sunk in some places fifty feet perpendicular. The extent of ground that moved was about *a mile and a quarter* from north to south, and 600 yards from east to west."

In no country on the globe have the inroads of the sea been so extensive as in Holland. In the

* The greatest depth of the straits between Dover and Calais is twenty-nine fathoms, which exceeds only by one fathom the greatest depth of the Mississippi at New-Orleans.

year 1421 the sea burst through the embankments of the river Meuse, and overflowed 72 villages, forming a large lake, called the Bies Basch. Thirty-five of these villages were irretrievably lost, and no vestige of them ever afterward discovered. Much of this district, however, is now an immense plain, having been filled up by an alluvial deposite, yielding abundant crops of hay, though uninhabited. A great portion of Holland lies lower than the sea, from which it is protected by extensive embankments or dikes.

In the year 1240, the island of North Strand measured from 9 to 11 miles in length, and from six to eight in length; towards the end of the 16th century it was only four miles in circumference, but still contained 9000 inhabitants. During one night, however, in the month of October, 1634, the sea swept over the whole island, carrying away 1300 houses and many churches, with 50,000 head of cattle, and more than 6000 inhabitants. There are now three small uninhabited islets where this fertile and populous island once stood.

CHAPTER XIV.

AGENTS WHICH DESTROY ROCKS, CONTINUED.

Destruction of the Land in Boston Harbour.—Chemical Action.—Causes which hasten it.—Destruction of Rocks proved by the Nature of the Soil.—Granite Soil.—Gneiss Soil.—Slate Soil.—Limestone Soil. — Soil of Red Sandstone Regions.—Freezing and Thawing.—Movement of Rocks by the Expansion of Ice.—Lightning.—Falling of Glaciers.

On our own coasts the inroads of the sea have in many instances been scarcely less striking and extensive. At Cape May, on the north side of Delaware Bay, it was proved by measurement that, from the year 1804 to 1820, the annual encroachment of the sea averaged nine feet; and at Sullivan's Island, near Charleston, South Carolina, the sea carried away a quarter of a mile of land in three years ending in 1786.

In relation to Boston Harbour, Professor Hitch cock remarks: "Here are numerous picturesque islands, the inner ones, nearly as far as Boston Light, being composed chiefly of diluvium; though on their shores, at a low level, not unfrequently we find argillaceous slate and other rocks that occur on the main land. But all the islands outward from the Great Brewster are merely naked masses of rock; and it would be natural to infer that the diluvium had been removed from these, even if we did not actually detect the process. But on the Great Brewster the work is going on before our eyes. Its eastern side is a high bank of diluvium, obviously wasting away by the action of the waves that roll in upon it from the wide Atlantic, while the extensive beach along its southern side is composed of the materials that have been swept away from its outer coast. The same process is seen going on upon the outer side of several other islands; and on Deer Island an extensive wall of stone has been erected by the United States government to arrest the progress of this degradation; which, if continued much longer there, would lay open the inner part of Boston Harbour to the fury of the northeasterly storms."*

Professor H. inclines to the belief that the whole of Boston Harbour, now dotted with small islands, was formerly one piece of solid land; "for," he remarks, "when we see so many islands scattered over its bosom, which seem obviously the wrecks of one continuous diluvial formation, and perceive that the rocks, wherever they occur, are only a con-

* Report of Geology of Massachusetts, p. 125.

tinuation of those occurring on the main land, the most cautious reasoner can hardly avoid the conclusion that such was the origin of this harbour. Nay, it is difficult to see why the same reasoning will not apply to the whole of Massachusetts Bay; and when we see with what tremendous force the ocean must, for ages, have battered the hard syenitic rocks of Cape Ann, and what an immense accumulation of sand, gravel, and bowlders has been made along the south shore of this bay, we feel almost prepared to adopt this theory," &c.

Lieutenant Mather, geologist to the first district of the State of New-York, thus speaks of the encroachments of the sea upon the shores of Long Island:

"Vast masses of the cliffs of loam, sand, gravel, and loose rocks, of which Long Island is composed, are undermined and washed away by every storm. The water on the ocean coast, to some distance from the shore, is almost always found to have more or less earthy matter in suspension, much of which, except during storms, is derived from the grinding up of the pebbles, gravel, and sand, by the action of the surf. This earthy matter is carried off during the flood tide, and in part deposited in the marshes and bays, and the remainder is transported seaward during the ebb, and deposited in still water. After a close observation, I have estimated that at least 1000 tons of matter is thus transported daily from the coast of Long Island, and probably that quantity, on an average, is daily removed from the south coast, between Montauk Point and Nepeaque Beach. This shore of 15 miles in length probably averages 60 feet in height, and is rapidly washing away. 1000 tons of this earth would be equal to about one square rod of ground, with a depth of 60 feet. Allowing this estimate to be within the proper limits, more than two acres would be removed annually from this portion of the coast. It is probable that any attentive observer would not estimate the loss of land there at less than this amount. Nearly one half the matter coming from the degradation of the land is supposed to be swept coastwise in a westerly direction. There are many evidences that the east end of Long Island was once much larger than at present; and it is thought probable that it might have been connected with Block Island, which lies in the direction of the prolongation of Long Island."

Chemical action.—Rocks are continually subject to decomposition, through the influence of chemical changes. Chemical affinity is constantly and successfully acting against the attraction of cohesion; in other words, the forces which strive to separate the particles of rocks are superior to those which tend to bind them together; the consequence is a silent, but sure, and often a rapid, decay of the solid structure of the globe. "It is painful," says Philips, "to mark the injuries effected by a few centuries on the richly sculptured arches of the Romans, the graceful mouldings of the early English architects, and the rich foliage of the decorated and later Gothic styles. The changing temperature and moisture of the air communicated to the slowly conducting stone, especially on the western and southern fronts of buildings, bursts the parts near the surface into powder, or, by introducing a new arrangement of the particles, separates the external from the internal parts, and causes the exfoliation or desquamation, as MacCulloch calls it, of whole sheets of stone parallel to the ornamental work of the mason. From these attacks no shelter can wholly protect; the parts of a building which are below a ledge often decay the first; oiling and painting will only retard the destruction; and stones which resist all watery agency, and refuse to burst with changes of temperature, are secretly eaten away by the chemical forces of carbonic acid and other atmospheric influences.

What is thought to be more durable than granite? Yet this rock is rapidly consumed by the decomposition of its feldspar, effected by carbonic acid gas; a process which is sometimes conspicuous even in Britain, but is usually performed in Auvergne, where carbonic acid gas issues plentifully from the volcanic regions."

Rocks which contain potash and soda are peculiarly exposed to decomposition, from the fact that these substances have a strong affinity for water and carbonic acid; while those that contain *iron* are no less perishable, from its strong attraction for *oxygen.*

Thus we see that rocks containing iron pyrites or *sulphuret of iron* are constantly crumbling to pieces; the oxygen of the air and water, combining with the sulphur, forms a *sulphate of iron* or copperas, the sulphuric acid of which acts powerfully on the rock, causing its rapid decomposition. Indeed, all rocks which have for one of their components the protoxides of the metals iron and manganese, soon fall into fragments when exposed to the atmosphere, from the circumstance that a second portion of oxygen combines with the metal, causing an increase of bulk, and, consequently, a disintegration of the rock.

As we shall hereafter enter somewhat minutely into the subject of the decomposition of rocks, when we come to treat of the practical application of geological science to economical purposes, our object at present will be attained if we succeed in convincing the reader that rocks are constantly, and often rapidly, undergoing decay.

An examination of the soil in any rocky district of country will suffice to convince us that it has been derived from the decomposition of the rocks in its vicinity. Thus, in a granite district, we find the soil made up of grains of quartz, spangles of mica, and white or brown looking particles, which are feldspar; and the finer portions, when examined with a microscope, will be found to consist of the same ingredients, containing, perhaps, minute specks of the brown oxide of iron, derived from the *pyrites* or protoxide of iron usually contained in that rock. Where *gneiss* is the prevailing rock, the soil will be composed of the same materials, only the mica is more abundant. In a *mica slate* region, we have a soil consisting chiefly of *mica*, mixed with grains of quartz. *Syenite* and *hornblende* rock produce a dark-coloured soil, containing much feldspar and decomposed hornblende, with but little quartz. The soil in the neighbourhood of *greenstone trap rocks* has a dark brown colour, containing pieces of the undecomposed rock, and is of a soft, loamy character, and exceedingly fertile. Where *slate rocks* prevail, the soil is of a blue colour, and forms a deposite of tough blue clay when transported by water. In *limestone countries* we can easily perceive that the soil is made up of the ingredients of this mineral; its colour, of course, depending on the colour of the rock, and the quantity of vegetable matter contained in it. Some of the magnesian limestones, or *dolomite*, decompose very rapidly when exposed to the atmosphere; and we have seen such in Litchfield county, Conn., forming, from their disintegration, large beds* of a coarse white sand.

* It is a somewhat remarkable fact, ascertained by Prof. Hitchcock, that it is a rare thing to find in the soil of a limestone country any calcareous matter. He states that out of 125 specimens of soils from all parts of the State of Massachusetts, and several of them from limestone tracts, only seven exhibited any effervescence with acids, and 3 *per cent.* was the greatest quantity of lime contained in any of them. From numerous experiments, he concludes that only one in 30 of the soils of Massachusetts contains calcareous matter. Quere: What becomes of it? If lime is a *simple substance* whose base is *calcium* (a metal), it is very difficult to believe that calcareous matter "is consumed or changed," as Prof. H. states to be a fact. Does this fact not lend great probability to the supposition that calcium is a gaseous compound, and may thus be produced by the secretory organs of animals?

In a *red sandstone* district we find the soil of a red colour, and made of grains of quartz, with oxide of iron and clay, and a few particles of undecomposed mica. So also *red slate* and *red porphyry* produce a red soil, and *graywacke* a light gray soil, full of smooth, rounded pebbles, evidently derived from the undecomposed fragments of the rock.

Some of the above rocks decompose more readily than others; but the correspondence of the soil with the characters of the underlying rocks proves very conclusively that it has been derived from the decomposition of the latter.

M. Daubuisson, an eminent French geologist, states that in a roadway in France, cut through granite, the rock was decomposed to the depth of *three inches in less than six years*.

"The disintegration of granite," says Lyell, "is a striking feature of large districts in Auvergne. This decay was called by Dolomieu 'la maladie du granite,' and the rock may, with propriety, be said to have *the rot*, for it crumbles to pieces in the hand. The phenomenon may, without doubt, be ascribed to the continual disengagement of carbonic acid gas from numerous fissures. In the Plains of the Po I observed great beds of alluvium, consisting of primary pebbles, percolated by spring water, charged with carbonate of lime and carbonic acid in great abundance. They are, for the most part, incrusted with calc sinter; and the rounded blocks of gneiss, which have all the outward appearance of solidity, have been so disintegrated by the carbonic acid as readily to fall to pieces.

"The subtraction of many of the elements of rocks by the solvent power of carbonic acid, ascending both in a gaseous state and mixed with spring-water in the crevices of rocks, must be one of the most powerful sources of those internal changes and rearrangement of particles so often observed in strata of every age. The calcareous matter, for example, of shells, is often entirely removed and replaced by carbonate of iron, pyrites, silex, or some other ingredient, such as mineral waters often contain in solution. It rarely happens, except in the limestone rocks, that the carbonic acid can dissolve all the constituent parts of the mass: and for this reason, probably, calcareous rocks are almost the only ones in which great caverns and long winding passages are found."

De la Beche* observes, that "rocks receive considerable chemical modification by the percolation of water through them. There is scarcely any spring-water which does not contain some mineral substances in solution, which it must have procured in its passage through the rocks. Now, though this quantity may be small when we regard the composition of any particular spring-water, yet, when we consider the soluble matter contained in the spring-waters of any given 1000 square miles of country, and that this subtraction of matter from rocks has been going on for ages, we may readily conceive that the chemical change may be greater than, at first sight, we might anticipate. We may also infer that the more soluble portions of rock have a constant tendency to be removed when exposed, not only to direct atmospheric influences, but also to the percolation of rain-water through them, so that most rocks would experience great difficulty in resisting chemical changes of this kind, and of preserving their original chemical nature, more particularly when elevated into the atmosphere."

In proof of the correctness of the opinion that water dissolves some of the elements and holds them in solution, we may refer to the large quantities of *lime* contained in the water of limestone countries, communicating the character of *hardness* to the water; and shown also by its deposition on

* Researches in Theoretic Geology, p. 86.

the inside of tea-kettles, steamboat boilers, &c.; also to the abundance of *silex* found in some springs possessing petrifying properties.

Dr. Turner, of London, has shown, that in the decomposition of rocks containing feldspar, producing the well-known substance called *porcelain clay*, the quantity of silex carried off by solution was enormous. He attributes this loss to the freedom with which it could be dissolved when exposed to the united action of water and alkali at the moment of passing from the state of combination which constitutes feldspar.* This loss of silex in many of the rocks would in a great measure destroy their cohesion, and powerfully tend to their rapid decomposition.

III. *The Freezing and Thawing of Ice.*

It is a matter of common observation that rocks are constantly undergoing changes in the Northern latitudes, especially from the freezing and thawing of ice. The amazing force exerted by freezing water is not generally known: that it is immense will appear from the following facts:

Mr. Boyle filled a brass tube, three inches in diameter, with water, and confined it by means of a moveable plug; the expansion, when it froze, took place with such violence as to push out the plug, though preserved in its situation by a weight equal to 70 pounds. The Florentine academicians burst a hollow brass globe, whose cavity was only an inch in diameter, by freezing the water with which it was filled; and it has been estimated that the expansive power necessary to produce such an effect was equal to a pressure of 27,720 pounds' weight. Bombs and cannon were burst in the same manner at Quebec *in the years* 1784 *and* 1785.†

* De la Beche.

† Philosophical Transactions of Edinburgh, 11, 23.

In the year 1819 we first discovered the important fact, that large masses of rock lying near the shores of ponds and lakes are moved towards the land by the expansion of the freezing ice. This was in Salisbury, Connecticut, where, in the north part of the town, may be seen two large ponds, separated from each other by a narrow strip of land, or, rather, rocks and stones, which have evidently been crowded from the bed of the lake by the same cause. By actual measurement on the ice, we ascertained that a rock weighing several tons was moved, during the space of one very cold night in January, several inches. Since then the same fact has been observed in Scotland and other places.*

In respect to this phenomenon, Prof. Hitchcock observes, "I am not aware that this phenomenon has been noticed on the eastern continent, and it has been but rarely observed on our own. It is well known that water, by an apparent exception to a general law, expands with great force when freezing, and even far below the freezing point. Over a large extent of surface this effect may be very considerable; and when bowlder-stones, lying in shallow ponds, become partially enveloped in the ice, they must feel the effect of this expansion, and be driven towards the shore, since the force must always act in that direction. As no counter force exists to bring back the rock to its original position, the ultimate effect must be to crowd it entirely out of the pond; and, perhaps, to this cause we may impute the fact, that on the margin of some ponds we find a ridge of bowlders; while the bottom, for a considerable extent, is free from them. The removal of rock masses in this manner was first noticed in Salisbury, Ct., and a statement published in vol. 9th† of the American Journal of Science," &c.

* Silliman's Journal, vol. 9.

† The above explanation, in nearly the same terms, will be found in our published account of the phenomenon in Silliman's Journal.

Perhaps there are no rocks which are more rapidly decomposed by the agency of frost than *quartz* and *trap* rocks. These often form perpendicular eminences, and, from their fissile texture, are easily split into layers. The water, collecting in these crevices, expands by freezing, and thus forces the rock into fragments, which fall apart on the melting of the ice, and accumulate at the base of the cliffs from which they have been precipitated, where again they are acted upon by the same cause, until they are reduced to minute particles. Vast accumulations from this cause may be seen at the base of East and West Rock, New-Haven; of the Palisades, on the Hudson; and at Monument Mountain, in Stockbridge, Mass.; and, indeed, wherever precipitous ledges of rocks are to be found.*

There is one agent concerned in the destruction of rocks to which we have not alluded, and that is *lightning*. That rocks are splintered into fragments by this cause, there can be no question, for numerous instances of this kind have been recorded. Mr. Lyell states that "at Funzie, in Fetlar, about the middle of the last century, a rock of mica slate 105 feet long, 10 feet broad, and in some places four feet thick, was in an instant torn by a flash of lightning from its bed, and broken into three large, and several smaller fragments. One of these, 26 feet long, 10 feet broad, and four feet thick, was simply turned over. The second, which was 28 feet long, 17 broad, and 5 feet in thickness, was hurled across a high point to the distance of 50 yards. Another broken mass, about 40 feet long, was thrown still farther, but in the same direction, quite into the sea. There were also many smaller fragments scattered up and down."

* Higgins states that the stone of which the colleges at Oxford are built, is one particularly affected by frost; and the consequence has been the almost entire destruction of the architectural beauty of those once elegant buildings.

To these causes we might add the *falling of glaciers* in Alpine countries. These are large bodies of ice found in elevated districts, above the line of congelation. These are continually descending towards the valleys; and they assist in the degradation of the land by breaking away fragments from the rocks, and transporting all the loose substances with which they come into contact. There are, therefore, usually found in the front of glaciers heaps of rocks and trees, which have been driven before them in their course. Sometimes they transport blocks of large dimensions, which could not otherwise have been forced into the valleys.

Such are some of the chief agents concerned in the destruction of rocks and the other solid portions of the globe; we are now prepared to consider the compensating powers of renovation.

CHAPTER XV.

AGENTS WHICH FORM ROCKS.

Quantity of Sediment in River-water.—In the Rhine—In the Yellow River—In the Ganges.—Deltas.—Delta in the Lake of Geneva—Lake Mareotis—North American Lakes.—Delta of Inland Seas—Of the Rhone—Of the Po—Of the Nile—Of the Ganges—The Mississippi.

We have seen that various causes are in continual operation to break down the solid parts of the earth's surface; let us now inquire what becomes of all these fragments. As there is no loss of matter, it follows that there must be a reproduction, as well as a destruction, of the land. Indeed, wherever water is found, there earthy deposites are going on; and the substance of all the strata which water is instrumental in forming, must be derived from the destruction of rocks.

Rivers are the chief agents in the transportation of these materials; and there are none which do not contain more or less earthy and sandy particles, originally derived from the rocks and banks skirting these streams or their tributary branches. As these materials possess a specific gravity greater than that of the water in which they are transported, they must consequently be deposited either in the bed of the rivers, or in the lakes or seas into which their waters flow.

Mr. Lyell very justly observes, that "the transport of sediment and pebbles to form a new deposite necessarily implies that there has been somewhere else a grinding down of rock into rounded fragments, sand, or mud, equal in quantity to the new strata. The gain at one point has merely been sufficient to balance the loss at some other. When we see a stone building, we know that somewhere, far or near, a quarry has been opened. The courses of stone in the building may be compared to successive strata; the quarry to a ravine or valley which has suffered denudation. As the strata, like the courses of hewn stone, have been laid one upon another gradually, so the excavation, both of the valley and quarry, have been gradual. To pursue the comparison still farther, the superficial heaps of mud, sand, and gravel, usually called alluvium, may be likened to the rubbish of a quarry, which has been rejected as useless by the workmen, or has fallen upon the road between the quarry and the building, so as to be scattered at random over the ground."

Quantity of Sediment in River-water.—We can easily calculate* how much solid matter is con-

* The first step in such calculations is to ascertain the average volume of water passing annually down the channel of a river. It is easy to ascertain this at any one particular time, by getting the mean depth, breadth, and velocity of the stream.

tained in a certain amount of river water, by taking a portion from different parts of the stream, and, after evaporating the fluid part, weigh the sediment In this manner it has been computed that the Rhine, when most flooded, contains one part in a hundred of mud in volume, and that the Yellow River in China contains one part to two hundred; and Sir George Staunton calculated from a number of experiments, that it brought down, in a single hour, two million cubic feet of earth, or forty-eight million daily: so that, if the Yellow Sea be taken to be 120 feet deep, it would require but 70 days to convert a square mile into firm land. Manfredi, the celebrated Italian philosopher, conceived the average proportion of sediment in all the running water on the globe to be one part to 175 of water, and that it would take 1000 years for the sediment carried down to raise the general level of the sea one foot. Major Rennell,* of the British army, states that a glass of water taken from the Ganges when at its height, yields about *one part in four* of mud.

Later observations by the Rev. Mr. Everest, show that this calculation was erroneous, or, more probably, a typographical error, and that the average quantity of solid matter was only 1-428th part by weight and 1-856th part in bulk, and that the total annual discharge is 6,368,077,440 cubic feet.

"In order," says Mr. Lyell, "to give some idea of the magnitude of this result, we will assume that the specific gravity of the dried mud is only one half that of granite (it would, however, be more); in that case, the earthy matter discharged in a year would be equal to 3,184,038,720 cubic feet of granite. Now about 12 1-2 cubic feet of granite weigh one ton; and it is computed that the great Pyramid

But as these conditions vary at different seasons of the year, we must make observations at different periods, and then take the *mean* of them all.

* Phil. Transact., 1781.

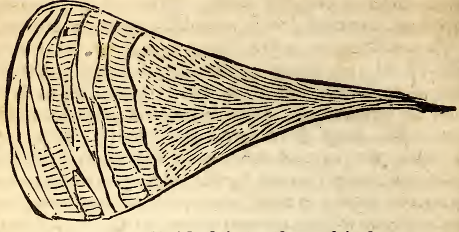
of Egypt, if it were a solid mass of granite, would weigh about 6,000,000 tons. The mass of matter, therefore, carried down annually, would, according to this estimate, more than equal in weight and bulk 42 of the great pyramids of Egypt, and that borne down in the four months of the rains would equal 40 pyramids. But if, without any conjecture as to what may have been the specific gravity of the mud, we attend merely to the weight of solid matter actually proved by Mr. Everest to have been contained in the water, we find that the number of tons' weight which passed down in the 122 days of the rainy season was 339,413,760, which would give the weight of 56 pyramids and a half; and in the whole year, 355,361,464 tons, or nearly the weight of sixty pyramids."* Mr. Lyell farther states, that "if a fleet of more than 80 Indiamen, each freighted with 1400 tons' weight of mud, were to sail down the river every hour of every day and night for four months continuously, they would only transport from the higher country to the sea a mass of solid matter equal to that borne down by the Ganges in the flood season; as the exertions of a fleet of about 2000 such ships going down daily with the same burden, and discharging it into the gulf, would be no more than equivalent to the operations of the great river. Yet, in addition to this, it is probable that the Burrampooter conveys annually as much solid matter to the sea as the Ganges"

Deltas.

A *delta* is a deposite of earthy matter, generally at the mouths of rivers, and is so called from its resemblance to the Greek letter Δ, which may be represented thus:

* The base of the great Pyramid of Egypt covers eleven acres, and its perpendicular height is about 500 feet.

Fig. 37.



Deltas may be divided into three kinds: 1. *Those which are formed in lakes;* 2. *Those in inland seas;* 3. *Those on the borders of the ocean.*

1. *Deltas in Lakes. Lake of Geneva.*—This lake is about 37 miles long, and from two to eight broad; the shape of the bottom being very irregular, the depth varying from 20 to 160 fathoms. The Rhine, where it enters at the upper end, is turbid and discoloured; but its waters, where it issues at the town of Geneva, are beautifully clear and transparent. An ancient town, called Port Vellais, once situated at the water's edge at the upper end, is now more than a mile and a half inland; this intervening alluvial tract having been acquired in about eight centuries. The remainder of the delta consists of a flat alluvial plain, about five or six miles in length, composed of sand and mud, a little raised above the level of the river, and full of marshes. In the centre of the lake, the depth of the water is from 120 to 160 fathoms, and it begins to grow shallower about a mile and three quarters from the mouth of the Rhine, through which space the fluviatile mud is always found at the bottom. Along this gradual slope, then, of 2 miles in length, the alluvial deposites are made; and if we could obtain a section of the accumulation formed in the last 800 years,* we should see a series of strata,

* De la Beche.

from 600 to 900 feet thick, along this whole extent, inclined at a very slight angle.

Lake Mareotis.—It is well known that this ancient lake of Egypt, together with the canal which connected it with the Canopic arm of the Nile, has been filled with mud and is become dry. Herodotus observes, "that the country round Memphis seemed formerly to have been an arm of the sea gradually filled by the Nile, in the same manner as the Meander, Achelous, and other streams had formed deltas. Egypt, therefore," he says, "like the Red Sea, was once a long narrow bay, and both gulfs were separated by a small neck of land. If the Nile," he adds, "should by any means have an issue into the Arabian Gulf, it might choke it up with earth in 20,000, or even, perhaps, in 10,000 years; and why may not the Nile have filled with mud a still greater gulf in the space of time which has passed before our age?"

North American Lakes.—There are numerous facts to show that these lakes occupy much less space than they once did, and that they are continually diminishing in size. Parallel to the southern shore of Lake Erie, and from four to eight miles distant from it, is a ridge of land, composed of sand, gravel, and rolled pebbles, such as now make the shore of the lake. This ridge is elevated from 140 to 200 feet above the lake, and it is now generally admitted to have once formed the lake shore. Wherever wells have been dug or excavations made in this ridge, fragments of decayed wood, bark, and often branches and trunks of trees, are found deeply imbedded in the soil, together with such species of shells as are now met with in the lake. Such ridges also exist at a considerable distance from the shores of Lake Erie, Superior, Michigan, and Huron, showing that their waters once occupied a much *higher level than they do at present.*

It has been ascertained by Dr. Bigsby, that the bottom of Lake Superior* consists of a very adhesive clay, containing shells of the species at present existing in the lake. When exposed to the air, this clay immediately becomes indurated in so great a degree as to require a smart blow to break it. It effervesces slightly with diluted nitric acid, and is of different colours in different parts of the lake; in one district blue, in another red, and in a third white, hardening into a substance resembling pipe-clay. "These lacustrine formations," Mr. Lyell remarks, "resemble the tertiary argillaceous and calcareous marls of lacustrine origin in Central France, as many of the genera of shells are the same."

Deltas of Inland Seas.—It is maintained by Mr. Lyell, that the rapid gain of land in the Baltic Ocean, especially the gulfs of Bothnia and Finland, is not only owing to the influx of sediment from numerous rivers, but also to a slow and general upward movement of the land itself, at the rate of several feet in a century.†

Delta of the Rhone.—We have already alluded to the delta formed by the river Rhone in the Lake of Geneva; but, after the river issues from that lake, its pure waters are again filled with sand and sediment by the impetuous Arve, which comes down from the highest Alps, bearing along immense quantities of granitic detritus, swept into the valleys by the glaciers of Mont Blanc. Before it enters the Mediterranean, whose blue waters it discolours for the space of six or seven miles, it receives vast quantities of transported matter from the Alps of

* Lake Superior is the largest body of fresh water in the world, being 1500 miles in circumference, and varying from 80 to 150 or 200 fathoms in depth, so that its bottom is in some parts 600 feet below the level of the Atlantic, and its surface as much above it.

† Lyell's Geology, vol. i., p. 437.

Dauphiny, and the primary and volcanic mountains of Central France.

Some of the proofs of the rapid advance of the land at the mouth of this river are the following: Strabo's description of the delta is so inapplicable to its present configuration as to attest a complete alteration in the physical features of the country since the Augustan age.

A portion of land, called Mese, and described by Pomponius Mela as being nearly an island, is now far inland. Notre Dame des Ports was a harbour in 898, but is now a league from the shore. Psalmodi was an island in 815, but is now a league from the sea. Several old lines of towers and seamarks occur at different distances from the present coast, all indicating the successive retreat of the sea, for each line has in its turn become useless to mariners; and so rapid is this retreat in some places, that the tower of Tignaux, erected on the shore as late as the year 1737, is now a French mile remote from it. The sea opposite the mouth of the Rhone deepens gradually from four to forty fathoms within a distance of six or seven miles, over which the discoloured water extends.*

It has been satisfactorily ascertained, that a great proportion, at least, of the earthy deposite at the mouth of the Rhone becomes changed into *solid rock.*

In the museum of Montpellier is a cannon taken up from the sea near the mouth of the river, imbedded in a crystalline calcareous rock. Large masses, also, are continually taken up of an arenaceous rock, cemented by calcareous matter, including multitudes of broken shells of recent species. Mr. Lyell states, "That the observations lately made on this subject corroborate the former statement of Marsilli, that the earthy deposites of the coast of Languedoc form a stony substance, for which rea-

* Lyell, from Bouche, Chorographie, &c.

son he ascribed a certain bituminous, saline, and glutinous nature to the substances brought down with sand by the Rhone. If the number of mineral springs charged with carbonate of lime, which fall into the Rhone and its feeders in different parts of France, be considered, we shall feel no surprise at the lapidification of the newly-deposited sediment in this delta."

Delta of the Po.—The Po and the Adige are the principal streams which drain, on the one side, a great crescent of the Alps, and, on the other, some of the loftiest ridges of the Apennines. From the northernmost point of the Gulf of Trieste down to the south of Ravenna, there is an uninterrupted series of recent accessions of land, more than 100 miles in length, which, within the last 2000 years, have increased from *two to twenty miles in breadth.** The town of Adria, which was a seaport in the time of Augustus, and in ancient times gave its name to the gulf, is now about twenty miles inland. Ravenna was also a seaport, but is now four miles from the sea. Spina, a very ancient city, originally built on an arm of the Po, on the border of the Adriatic, is now more than twelve miles from the sea. The deposites consist partly of mud and partly of rock, the rock being composed of calcareous matter, incrusting shells. Olivi found some deposites of sand, and others of mud, extending half way across the Gulf of Trieste, and states that their distribution along the bottom was determined by the prevailing current.

Delta of the Nile.—Some of the ancient poets have described Egypt as "the gift of the Nile;" but, as Lyell remarks, we have no authentic memorials for determining with accuracy the dates of successive additions made to the habitable surface of that country. Major Rennell, after exploring the country, states that there is no room to doubt that

* Brocchi, vol. 1, p. 59.

the sea once washed the base of the rocks on which the Pyramids of Memphis stand; the *present* base of which is washed by the inundation of the Nile, at an elevation of seventy or eighty feet above the Mediterranean.

The Nile once entered the sea by seven principal mouths, two of which are now entirely blocked up by sand, and have disappeared. The city of Foah, which in the fifteenth century stood on one of these branches, is now more than a mile inland, and *Pharos*, anciently an island, which Homer says was one day's voyage by sea from Egypt, is now a portion of the continent.* An analysis of the mud of the Nile gives, according to Girard, one half of argillaceous earth, and about one fourth of carbonate of lime, nearly one tenth of carbon, the remainder consisting of water, silex, oxide of iron, and carbonate of magnesia. At a small distance from the shore of the delta, the depth of the Mediterranean is about twelve fathoms; it then gradually increases to fifty, and then suddenly descends to three hundred and eighty fathoms, which is supposed to be nearly the original depth of the sea.

Deltas of the Ocean.—These are variously modified by the influence of tides and currents, which prevail to a greater or less extent in every ocean, as they often distribute the transported sediment to distant or, perhaps, unknown places of deposite.

Delta of the Ganges.—The area of this delta is considerably more than double that of the Nile, and its head commences at least 220 miles in a direct line from the sea. Its base is 200 miles long, and it is bounded on either side by an arm of the Ganges. Near the sea it is intersected by a labyrinth of rivers and creeks, generally filled with salt water, and forms a wilderness inhabited by tigers and alligators. The Ganges pours such a quantity

* Odys., book iv., v. 355.

of mud and sand into the Bay of Bengal in the flood season, that the sea only recovers its transparency at the distance of 60 miles from the coast. The water gradually deepens from four to sixty fathoms at the distance of 100 miles from the coast, so that the general slope of the new strata is very gradual. Opposite the mouth of the Hoogly river, four miles from the nearest land of the delta, a new island was formed about twenty years ago, called Edmonstone Island, on the centre of which a beacon was erected as a landmark in 1817. In 1818 the island had become two miles long and half a mile broad, and was covered with shrubs and vegetation, and houses were built upon it. At the present time, however, only a small sandbank remains, the rest having been washed away.* Major Colebrook states, that islands many miles in extent have been formed during a period far short of a man's life by the collection of sandbanks, and while the river is forming new islands in one part it is sweeping away old ones in others. Those newly formed are soon overrun with reeds, long grass, the tamarix Indica, and other shrubs, forming impenetrable thickets, where deer, tigers, buffaloes, and other wild animals take shelter.

Delta of the Mississippi.—The delta of the Mississippi may be described as a long, narrow tongue of land, consisting mainly of the banks of the river. This portion of land has advanced many leagues since New-Orleans was built, and is still advancing with great rapidity, while the Gulf of Mexico is gradually but constantly growing shallower, so that it now rarely exceeds ten fathoms in depth in any part. In consequence of the numerous sandbars deposited at the mouth of the Mississippi, its entrance is exceedingly difficult and dangerous.

The reason why a delta is not formed at the mouth

* Trans. Asiatic Soc., vol. vii., p. 14.

of the Amazon, in South America, is thus stated by Mr. Lyell: "A great current flows along the coast of Africa from the south, which, when it reaches the head of the Gulf of Guinea, and is opposed by the waters brought to the same spot by the Guinea current, streams off in a westerly direction, and pursues its rapid course quite across the Atlantic to the Continent of South America. Here one portion proceeds along the northern coast of Brazil to the Caribbean Sea and the Gulf of Mexico. Captain Sabine found that this current was running with the astonishing rapidity of four miles an hour where it crosses the stream of the Amazon, which river preserves part of its original impulse, and has its waters not wholly mingled with those of the ocean at the distance of 300 miles from its mouth. The sediment of the Amazon is thus constantly carried to the northwest as far as the mouths of the Oronoco, and an immense tract of swamp is formed along the coast of Guiana, with a long range of muddy shoals bordering the marshes, and becoming converted into land. The sediment of the Oronoco is partly detained and settles near its mouth, causing the shores of Trinidad to extend rapidly, and is partly swept away by the Guiana current into the Caribbean Sea. According to Humboldt, much sediment is carried again out of the Caribbean Sea into the Gulf of Mexico. The rivers also, which descend from the high platform of Mexico, between the mouths of the Norte and Tampico, where they arrive swollen by tropical rains at the edge of that platform, bear down an enormous quantity of rock and mud to the sea; but the current setting across their mouths prevents the growth of deltas, and preserves an almost uniform curve in that line of coast." In this manner we may account for the existence of those numerous islands in the Caribbean Sea.

Such are a few of the facts connected with the deposite of those materials which have been derived from the disintegration of the solid portion of the earth's surface, and carried by means of running water into lakes and seas. But it must not be supposed that all is deposited upon the shores; on the contrary, by far the largest portion is carried out to sea, and, by means of currents, swept to a distance. For example, if we look at the German Ocean, we shall see how small a part is deposited on the shores of Europe. The mean depth of this ocean is about 31 fathoms, and it is traversed by several enormous banks, one of which, called the Dagger Bank, extends upward of 354 miles in length; another extends 110 miles; and a third 105; and the whole superficies of these enormous shoals is equal to one fifth of the whole area of the German Ocean, or one third the whole extent of England and Scotland. The average height of the banks measures about 78 feet, consisting of fine and coarse silicious sands, mixed with broken corals and shells.*

All these materials are deposited in regular strata, as we see in a sandbank or the sides of a river; and we have only to suppose them hardened into stone, to have an exact counterpart of the sandstones, slates, and other rocks which we daily see upon the land. The accumulations being successive, and sometimes interrupted, must give to such deposites the character of stratification. We thus learn how rocks have been produced at an earlier period. The beds of clay and of sand deposited in rivers, lakes, and seas, will necessarily contain the remains of those animals which may die and be car-

* It has been found that *emery* powder, used for polishing glass, takes more than an hour to sink one foot. Now if mud, which is composed of particles twice as coarse, falls at the rate of two feet per hour, should be discharged into that part of the Gulf Stream which preserves a mean velocity of three miles an hour for a distance of 2000 miles, it is evident that in 28 days these particles will be carried 2016 miles, and will have fallen only to a depth of 224 fathoms.

ried into them during the process of deposition. If we disturb any of these beds, we find shells, bones, or vegetables, which will differ according to the circumstances under which the beds have been formed. In the deposites of fresh-water rivers, the remains of fresh-water animals will be found; in those of the sea, marine animals will be abundant.

Geologists have accordingly availed themselves of this important fact; and when they find the remains of terrestrial and fresh-water animals in a deposite, they call it a fresh-water bed, and thus obtain some information concerning the circumstances under which it was formed.

Let us now suppose that these beds of clay and of sand at the bottom of seas and of rivers are raised above the surface of the water, and exposed to heat and pressure, in what would they differ from any similar beds associated with known rocks? Is it beyond the bounds of possibility that this may eventually occur, and what is now covered by water may become dry ground? Geologists believe that this has happened in the instance of all those rocks whose stratified texture evinces that they were at a former period produced by deposition; and it is not unphilosophical to believe, that what has happened once may happen again. Indeed, it is well ascertained that the new-formed strata of the seas of Asia Minor consist of *stone*, and not of loose, incoherent materials. Almost all the streams and rivers, like many of those in Tuscany and the south of Italy, hold abundance of carbonate of lime in solution, which serves to bind together the sand and gravel into solid sandstones and conglomerates

CHAPTER XVI.

AGENTS WHICH FORM ROCKS (CONTINUED).

Agents which form Rocks.—Coral Animalcules.—Coral Reefs; how formed.—General Form.—Submarine Volcanoes.—Basil Hall's description of Loo Choo.—Montgomery's poetical Description.

Coral animalcules.—The nature of coral animalcules is not, generally, correctly understood; many persons supposing that the hard calcareous substance which goes under the name of coral is the animal itself. But the stony substance may be correctly compared to an internal skeleton; for it is surrounded by a soft animal substance, capable of expanding itself, and, when alarmed, of contracting and drawing itself almost entirely into the hollows of the hard coral. Though often beautifully coloured in their own element, the soft parts become, when taken from the sea, nothing more in appearance* than a brown slime spread over the stony nucleus. As one generation of these animals passes away, the structure which they have reared serves as the foundation on which a succeeding race continues to build.

It was a prevailing opinion among naturalists not many years since, that coral animals had the power of building up steep and almost perpendicular walls from great depths in the sea; but it is now pretty well ascertained that they cannot live in water of great depths, and that they only incrust the tops of submarine mountains with a calcareous covering a few fathoms thick.†

* Ehrenberg Nat. und. Bild. der Coralleninseln, &c.

† It has been lately proved that the branched corals, which do

"In some parts of the sea," says Mantell, "the eye perceives nothing but a bright sandy plain at bottom, extending many hundred miles, but in the Red Sea the whole bed of this extensive basin of water is absolutely a forest of submarine plants and corals. Here are sponges, madrepores, corals, fungiæ, and other polyparia, with fuci, algæ, and all the variety of marine vegetation covering every part of the bottom, and presenting the appearance of a submarine garden of the most exquisite verdure, and enamelled with animal forms resembling, and even surpassing in splendid and gorgeous colouring, the most celebrated parterres of the East.

Ehrenberg, the distinguished German naturalist, whose labours have so greatly advanced our knowledge of the infusoria, was so struck with the magnificent spectacle presented by the polyparia in the Red Sea, that he exclaimed with enthusiasm, "Where is the paradise of flowers that can rival in variety and beauty these living wonders of the ocean? Some have compared the appearance to beds of tulips or dahliahs; and, in truth, the large fungiæ, with their crimson disks and purple and yellow tentacula, bear no slight resemblance to the latter."—Vol. ii., p. 486.

Coral reefs, however, are by no means the exclusive work of zoophytes, for we find imbedded in them a great variety of shells, such as oysters, clams, muscles, echini, together with the skeletons of fishes. The conversion of coral reefs into islands is effected in the following manner. The reefs, which just raise themselves above the level of the sea, are usually of a circular or oval form, and surrounded by a deep and often unfathomable ocean. These, which are supposed to be built on the verge

not form solid masses, live at great depths. Off Cape Horn they have been brought up in 50 fathoms of water, and near the Cape of Good Hope they have been obtained at a depth of 100 fathoms.

of a submarine crater, contain in the centre a comparatively shallow lagoon or lake, where there is still water, and on the borders of which the smaller and more delicate kind of zoophytes find a tranquil abode, while the hardier species live on the exterior margin of the islet, where a great surf usually breaks. When the reef is of such a height that it remains almost dry at low water, the corals leave off building.

A continuous mass of solid stone is now seen, composed of the shells of mollusks and echini, with their broken-off prickles and fragments of corals united by calcareous sand produced by the pulverization of shells. Fragments of coral limestone are thrown up by the waves, until the ridge becomes so high that it is covered only during some seasons of the year by the high tides. The heat of the sun often penetrates the mass of stone when it is dry, so that it splits in many places. The force of the waves is thereby enabled to separate and lift blocks of coral frequently six feet long and three or four in thickness, and throw them upon the reef. Afterward the calcareous sand lies undisturbed, and offers to the seeds of trees and plants cast upon it by the waves, a soil upon which they rapidly grow to overshadow its dazzling white surface. Trunks and branches of trees, which are carried by the rivers from other countries and islands, find here, at length, a resting-place after their long wanderings; with these come some small animals, such as lizards and insects, for the first inhabitants. Even before the trees form a wood, the sea-birds nestle here; strayed land-birds take refuge in the bushes; and, at a much later period, when the work has been long since completed, man appears and builds his hut on the fruitful soil.*

Most coral reefs contain a greater or less pro-

* Lyell and Kotzebue.

portion of compact limestone, which has doubtless been produced by chemical precipitation. As the coral animals* perish and become decomposed, the lime is set free to a considerable extent, and under circumstances favourable to deposition, and so the mass becomes of a compound or mixed character. The Pacific Ocean abounds in coral to the 30th degree of latitude on each side of the equator; so also do the Arabian and Persian Gulfs. On the east coast of New-Holland is a reef 350 miles in length; and between that country and New-Guinea there is a chain of coral 700 miles long. The Maldivas, in the Indian Ocean, are coral reefs extending 480 geographical miles north and south. These are circular islets, the largest being 50 miles in diameter, the centre of each being a lagoon from 15 to 20 fathoms deep, and on the outside of each island, at the distance of two or three miles, there is a coral reef, immediately outside of which the water is generally more than 150 fathoms deep.

The following cut will serve to illustrate the general shape and formation of these islands.

Fig. 38.

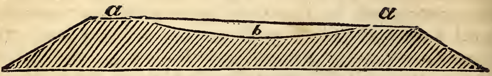
Coral reefs or islands.

The following section will enable the reader to get a correct idea of the usual form of such islands.

In proof that the circular forms of these coral

* It is stated by Lieut. Nelson, that among the Bahama Islands, zones of coral enclose tranquil basins, within which the decomposition of numerous zoophytes produces a soft, white calcareous mud, so much resembling chalk that specimens deposited in the Museum of the Geological Society of London cannot be distinguished from some of the common soft chalk of England.

Fig. 39.



a a, the habitable part of the island. *b*, the lagoon.

islands are owing to their being the crusts of submarine volcanoes, Mr. Lyell states that every island yet examined in the wide region termed Eastern Oceanica, consists either of volcanic rocks or coral limestones; and that in some of them, as in Gambier's Group, rocks of porous lava actually rise up in the centre. That many of these islands have been raised from the sea by volcanic action, there can be no doubt; for on the summit of the highest mountain in Tahiti, an island composed almost entirely of volcanic rocks, there is a distinct stratum of fossil coral, resembling that of modern reefs. In addition, we may state that MM. Quoy and Gaimard describe the shores of Coupang and Timon as formed of coral beds twenty-five or thirty feet in thickness, and that *above these* repose vertical beds of slate, traversed by quartz; also, that in the Isle of France, a coral bed ten feet thick occurs between two lava-currents.

One circumstance in relation to these coral islands is worth remarking, and that is the deep, narrow passage which almost invariably leads from the sea to the lagoon in the centre. This is kept open by the water rushing in during high tide and rushing out again at low tide, and with such force as to prevent the coral animals from raising their structure. In the same manner, the deepest channel of our harbour (Gedney's Channel) is kept open by the strong ebb tide which sweeps out the sand, which would otherwise soon block it up, and deposites it in the ocean. But if we follow up the Hudson to the Overslaugh, near Albany, where the tide is scarcely felt, we find the channel constantly blocking up with sand, and obstructing navigation, because the current is too sluggish to carry down the sand,* gravel, and mud which it brings down from above.

The growth of coral is generally supposed to be very slow. In the Pacific, an anchor was discovered in seven fathom water, still preserving its original form, but entirely incrusted with coral. It is stated, in Captain Beechey's expedition to the Pacific, that no positive information could be obtained of any channel having been filled up by coral within a given period; and that several reefs had remained for more than half a century at about the same depth from the surface. The natives of the Bahama Islands point out certain corals now growing in the sea, which, according to tradition, have been living in the same spot for centuries. "It is supposed," says Lyell, "that some of them may vie in age with the most ancient trees of Europe."

Captain Basil Hall thus describes a coral reef near the great island of Loo Choo:

"When the tide has left the rock for some time dry, it appears to be a compact mass, exceedingly hard and rugged; but, as the tide rises, and the waves begin to wash over it, the polypi protrude themselves from holes which were before invisible. These animals are of a great variety of shapes and sizes, and in such prodigious numbers that in a short time the whole surface of the rock appears to be alive and in motion. The most common form is that of a star, with arms or tentacula, which are moved about with a rapid motion in all directions, probably to catch food. Others are so sluggish that they may be mistaken for pieces of the rock, and are generally of a dark colour. When the coral is broken about high-water mark, it is a solid, hard stone; but if any part of it be detached at a spot

* The only effectual remedy in such cases is to increase the velocity of the water by narrowing the channel.

where the tide reaches every day, it is found to be full of polypi of different lengths and colours; some being as fine as a thread, of a bright yellow, and sometimes of a blue colour. The growth of coral appears to cease when the worm is no longer exposed to the washing of the sea. Thus a reef rises in the form of a cauliflower, till the top has gained the level of the highest tides, above which the animalcules have no power to advance, and the reef, of course, no longer extends upward."

We shall conclude our remarks on the formation of coral rocks with the following extract from the "Pelican Island," a poem by James Montgomery.

"I saw the living pile ascend,
The mausoleum of its architects,
Still dying upward as their labours closed;
Slime the material, but the slime was turned
To adamant by their petrific touch.
Frail were their frames, ephemeral their lives,
Their masonry imperishable. All
Life's needful functions, food, exertion, rest,
By nice economy of Providence,
Were overruled, to carry on the process
Which out of water brought forth solid rock.
Atom by atom, thus the mountain grew
A coral island, stretching east and west;
Steep were the flanks, with precipices sharp,
Descending to their base in ocean gloom.
Chasms few, and narrow, and irregular,
Formed harbours safe at once and perilous;
Safe for defence, but perilous to enter.
A sea-lake shone amid the fossil isle,
Reflecting in a ring its cliffs and caverns,
With heaven itself seen like a lake below."

CHAPTER XVII.

AGENTS WHICH FORM ROCKS (CONTINUED).

Springs.

Springs, how Supplied.—Artesian Wells.—Mineral and Thermal Springs.—Calcareous Springs.—Travertin.—Silicious Springs.—Geysers of Iceland.—Sinter.—Hot Springs of St. Michael.—Silicious Deposites.—Ferruginous Springs.—Naptha and Asphaltum Springs.—Pitch Lake of Trinidad.

Springs are mostly supplied by water which falls in rain on the surface of the earth. This is shown by the fact that, after a long drought, they are apt to dry up, and in wet seasons they flow most copiously. Every person is aware that porous soils absorb water with great facility, as such ground soon becomes dry after heavy showers. The depth to which we have to penetrate before reaching water depends in a great degree on the nature of the strata beneath. Thus, if a bed of clay lies under loose sand and gravel, it serves as a non-conductor of water, and, of course, we shall find water probably before we reach it. The same is often the case if a stratum of rock lies beneath the soil, unless the shape of the surface is such that the water is carried off by descending to a lower level. As a general rule, in sinking wells it is necessary to penetrate near to some stratum impervious to water, before we shall meet with a sufficient supply of this element; for here the water accumulates as in a reservoir, and is ready to flow out into any opening which may be made. This may be illustrated by the effect of the tides in the Thames, near London. The river here flows through a bed of gravel overlying clay, and the porous superstratum is alternately saturated by the water of the Thames as the tide rises, and then drained again to the distance of several hundred feet from the banks when the tide falls, so that the wells in this tract regularly ebb and flow.

We can now understand why water flows out on the surface, at the base, or on the side of a hill; the upper strata are porous, while the subjacent are composed of clay or other retentive soils. Springs which are not affected by long droughts probably owe the constancy and uniformity of their volume to the great extent of the subterranean reservoirs with which they communicate.

Artesian Wells.—In *Artois*, in France, a method has long been practised of obtaining water by boring the earth with a large auger from three to four inches in diameter. Hence such wells are called *Artesian.* This practice is founded on the fact that there are sheets or veins of fresh water at various depths in the earth. When a rock is met with, it is triturated with an iron rod, which is alternately elevated and dropped by machinery; the materials, thus being reduced to a powder, are readily extracted. In this manner Mr. Disbrow, at Holt's Hotel in the city of New-York, penetrated through 126 feet of stratified sands, blue clay, and river mud, when he came to the gneiss rock which underlies the whole island; he then bored this rock 500 feet, the upper 200 with an auger 3 inches in diameter, and the remainder with two and a half inch. He also penetrated the earth at the corner of Bleecker-street and Broadway, with an auger 7 inches in diameter, to the depth of 448 feet, 406 of which is in solid rock. This well furnishes 120,000 gallons of excellent water in 24 hours; and the water rises within 20 feet of the surface. Where the hole is made into the earth, in order to prevent the sides from falling in, as well as the escape of the water into the adjacent soil, a jointed pipe of wood or metal is introduced. When a vein of water is struck, it often happens that the fluid rushes violently up the tube, and plays over the top like a fountain. This is often owing to the disengagement of air or carbonic acid gas. At Hammersmith, in England, the rush of water from a depth of 360 feet was so great as to inundate several buildings and do considerable damage; and in another place, a sufficient stream was obtained to turn a wheel, and raise the water to the upper surface of the houses. At Tours, in France, at the depth of several hundred feet, the water rose 32 above the level of the soil, and the discharge amounted to 300 cubic yards in 24 hours. Excavations have been made in this manner to a depth of 1200 feet.

Mineral and Thermal Springs.—Springs are rarely, if ever, quite pure, owing to the solvent property of water, which, percolating through the earth, always becomes more or less charged with foreign matter. Carbonate, sulphate, and muriate of lime, muriate of soda, and iron, are frequently present in spring-waters. Some are more highly charged with these substances than others, and are, accordingly, called *mineral springs.* In these the foreign ingredients are in a state of chemical solution, and, accordingly, so intimately blended with the water as not to effect its clearness. The use of such waters strongly teaches us the force of habit; for though at first they may be highly nauseous and disagreeable, in a short time they lose these properties and become pleasant to the taste.

Warm springs have received the name of *thermal*, and they rise up through all kinds of rock, as granite, gneiss, limestone, or lava, but are most frequent in volcanic countries. In many volcanic regions, as in Italy, jets of steam issue from fissures at a temperature high above the boiling point; and if such volumes of steam should come in contact with strata filled with cold water, they would give rise to thermal springs of every degree of temperature.

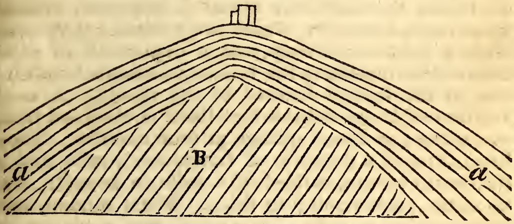
Calcareous Springs.—Our chief object in noticing springs in this place is to point out how they are agents in the formation of rocks: and we first call the attention of the reader to those charged with lime or calcareous matter, as the phenomena connected with them are of high interest in geology. It is a fact generally known, that water has the property of dissolving the calcareous rocks over which it flows. Springs that contain carbonic acid in solution are capable of dissolving a much larger quantity of calcareous matter than rain water; and, owing to the dissipation of the acid in the atmosphere, such springs throw down large quantities of lime, in the form of a loose and porous rock, called *tufa*, or in a more compact form, called *travertin.** Such springs are more commonly found in limestone districts, though not confined to them; for in Clermont, near Central France, one of these springs issues from a volcanic rock resting on granite, which has formed, by its deposites, a mound of white concretionary limestone 240 feet in length, 16 feet high, and 12 wide.

Among the Apennine hills in Italy, and especially in Tuscany, so much calcareous matter has been deposited by the innumerable springs scattered over the country, that the whole ground is covered with limestone, and sounds hollow beneath the foot. In other places in the same country, Mr. Lyell states that he saw compact rocks formed in this manner, descending the slanting sides of hills much in the manner of lava currents, except that they were of a white colour, and terminate abruptly when they reach the course of a river.

* This stone was called by the ancients *lapis Tiburtinus*, being formed in great quantity by the river Anio, at Tibur, near Rome. *Travertin* is an abbreviation from *Transtiburtinus*.

At the hill of San Vignone, in Tuscany, a thermal spring issues from the summit of a rocky hill 100 feet high, composed of black slate and serpentine.

Fig. 40.



B, Serpentine and Slate. *a a*, Limestone Deposite.

A large mass of tufa, *a a*, or travertin in regular strata, descends on each side of the hill; one of the strata being compact, and about 15 feet thick, serves as an excellent building stone; while the other, descending 250 feet in length, forms a mass about 200 feet deep. So rapid is the deposition of lime at these springs, that half a foot of solid limestone is deposited every year in a conduit pipe, inclined at an angle of 30 degrees. Where the water flows more slowly, the deposite is more compact, and rings when struck with a hammer; but where its current is swifter, it is cellular and porous, like the Paris buhr millstone; sometimes it assumes a mammillary form, and scales off in thin layers, like the coats of an onion.

At the baths of San Filippo, among the Apennines, the water which supplies the baths falls into a pond, where it has been known to deposite a solid mass 30 feet thick in 20 years. A manufactory of medallions, in basso-relievo, is carried on at these baths. The water is conducted by canals into several pits, in which it deposites carbonate and crystals of sulphate of lime. After being thus freed from its grosser parts, it is conveyed by a tube to the summit of a small chamber, and made to fall through a small space of 10 or 12 feet. The current is broken in its descent by numerous crossed sticks, by which the spray is dispersed around upon certain moulds, which are rubbed lightly over with a solution of soap, and a deposition of solid matter like marble is the result, yielding a beautiful cast of the figures formed in the mould. A hard stratum of stone about a foot thick is obtained from the waters of these springs in four months. They have formed a deposite of limestone a mile and a quarter in length, a third of a mile in breadth, and in some places 250 feet thick. What renders this limestone of peculiar interest to the geologist, is the spheroidal or globular form which it assumes. Some of the concentric masses are composed of laminæ so thin that 60 may be counted in the thickness of an inch. This tendency to a globular structure doubtless arises from the facility with which the calcareous matter is precipitated in nearly equal quantities on all sides of any fragment of shell or wood, or any inequality of the surface over which the mineral water flows. Such concretions often form on the internal surface of steam boilers, the head of a nail or rivet forming the nucleus, which becomes covered by a series of overlapping crusts of calcareous matter, usually *sulphate of lime.*

Near Viterbeo, in Italy, there is a hill about 20 feet high and 500 yards in circumference entirely composed of limestone deposited from water. This has been quarried for building-stone, and the strata have a concentric and radiated structure. A spring near Civita Vecchia, in Italy, deposites alternate beds of a yellowish travertin and a white granular rock, not distinguishable either in grain, colour, or composition from statuary marble.

Sir Humphrey Davy thus describes the properties of a small lake in the Campagna between Rome and Tivoli: "I have found by experiment that the most tranquil part of the lake, even after being agitated and exposed to the air, contained in solution more than its own volume of carbonic acid gas, with a very small quantity of sulphuretted hydrogen. Its high temperature, which is pretty constant at 80° of Fahrenheit, and the quantity of carbonic acid that it contains, render it peculiarly fitted to afford nourishment to vegetable life. The banks of travertin are everywhere covered with reeds, lichen, confervæ, and various kinds of aquatic vegetables; and at the same time that the process of vegetable life is going on, the crystallizations of the calcareous matter, which is everywhere deposited in consequence of the escape of carbonic acid, likewise proceed. There is, I believe, no place in the world where there is a more striking example of the opposition or contrast of the laws of animate and inanimate nature, of the forces of inorganic chemical affinity, and those of the powers of life."*

Mr. Lyell supposes that the zoophytic and shelly limestones, which constitute the coral reefs of the Indian and Pacific Oceans, are supplied with carbonate of lime and other mineral ingredients from submarine springs, and that their heat, as well as their earthy and gaseous contents, may promote the development of corals, sponges, and testacea, just as vegetation is quickened by similar causes in the lake above described by Sir Humphrey Davy. Sulphate of lime or *gypsum* is deposited by these springs, which are, however, few in number, which contain sulphuric acid and sulphuretted hydrogen. *Marl* is a deposite of carbonate of lime from ancient lakes or seas.

Silicious Springs.—The quantity of other mineral

* Consolations in Travel, p. 123.

ingredients with which springs are impregnated is small in comparison to lime, yet many of them, especially thermal springs, contain more or less silicious matter in solution. Indeed, to dissolve silica, it is necessary that water should be raised to a high temperature.

The hot springs of Iceland, called *Geysers*, afford the most remarkable example of the deposition of silex. The circular reservoirs into which the water falls are filled in the middle with a variety of opal, and round the edges with a silicious deposite called *sinter*. In some places a vesicular rock is formed, containing portions of vegetables more or less completely silicified; and among other deposites is that of clay and silica, called *tripoli*. The silex is deposited because the water, when cooled by exposure to the air, is unable to hold as much silica in solution as when it first issues from the earth, at a temperature of near 200° of Fahrenheit.

Dr. Webster describes the hot springs of St. Michael, in the Azores, as rising through volcanic rocks with a temperature varying from 93° to 207° Fahrenheit, and depositing vast quantities of silicious matter, which envelops the grass, leaves, and other vegetable substances that fall within their reach. These they render more or less fossil. The vegetables may be observed in every state of petrifaction. He found branches of the ferns, which now flourish in the island, completely petrified, preserving the same appearance as when vegetating, excepting the colour, which is now ash-gray. Fragments of wood occur more or less changed; and one entire bed, from three to five feet in depth, is composed of the reeds, so common in the island, completely mineralized, the centre of each joint being filled with delicate crystals of sulphur.

The silicious deposites are both abundant and various; the most abundant occur in layers from a quarter to half an inch in thickness, accumulated to the depth of a foot and upward. The strata are nearly always parallel and horizontal, though sometimes slightly undulating. The silex forms stalactites, often two inches in length, in the crevices of the silicious deposites, and these are frequently covered with small, brilliant quartz crystals. Compact masses of silicious deposites, broken by various causes, have been re-cemented by silica, and the compound is represented as very beautiful. Some of the elevations of this rock or *breccia* are upward of thirty feet in height.

The general deposite appears to be considerable, and to form low hills. The colours of the clay and silicious substances are very various, and even brilliant; white, red, brown, yellow, and purple being the principal tints. Where the acid vapours reach the rocks, they deprive them of their colours. Sulphur is abundant, and the springs occur in a district of lava and trachyte.* It is highly probable, that in a region of submarine volcanoes, the springs which boil up into the ocean from the bowels of the earth are so saturated with silicious matter as to form extensive deposites far and wide over the bed of the sea; and there becoming interstratified with shelly and calcareous deposites, may form the substratum or foundation on which coral animalcules rear heir gigantic structures.

Ferruginous Springs.—More or less iron is held in solution by nearly all springs, and often in such quantity as to stain the rocks or herbage through which the waters flow, and serving to bind together sand and gravel into solid masses. There can be no doubt that iron is conveyed in considerable quantities from the interior of the earth into lakes and seas, and there acts as a colouring and cementing principle among the silicious and carbonaceous deposites which are continually forming. We have

* Edinburgh Phil. Journal, vol. vi., p. 306.

already seen that many sandstones, which were doubtless the sedimentary strata of ancient waters, are bound together and coloured red by iron; and among such rocks we often meet with carbonate and sulphuret of iron, as we now find the same metal existing in the form of a carbonate or a sulphate in chalybeate springs. Dr. James found, in his expedition to the Rocky Mountains, that the thermal springs of the Washita deposite a very copious sediment, composed of silex, lime, and iron. There are numerous springs in this country which deposite both calcareous as well as silicious matter.

Brine Springs.—There are some springs which yield so large a quantity of muriate of soda (table-salt), that one fourth the weight of water may be extracted by evaporation. Together with these, there are usually intermixed more or less carbonate and sulphate of lime, magnesia, and other mineral ingredients. The salt-springs of Cheshire (England) rise up through strata of sandstone and red marl, which contain large beds of rock-salt; and they are known to have flowed more than 1000 years. Brine springs are supposed to owe their origin to beds of fossil salt. The waters of the Dead Sea contain large quantities of muriatic salts, which Dr. Daubeny thinks lends countenance to the volcanic origin of the surrounding country, as such salts are the frequent products of volcanic eruptions. There are numerous salt-springs in the United States, which will be described particularly when we come to treat of descriptive geology.

Naptha and Asphaltum Springs.—We find springs in various parts of the world impregnated with petroleum and other substances allied to it, such as bitumen, naptha, asphaltum, and pitch; which, in many cases, it is presumed, owe their origin to subterranean fires, which raise or sublime the more subtle parts of the bituminous matter contained in rocks.

The most abundant petroleum springs known are those on the river Irawadi, in the Birman Empire; there being 520 wells in one locality, which yield annually 400,000 hogsheads of petroleum.

Fluid bitumen oozes from the bottom of the sea, on both sides of the Island of Trinidad, and rises up to the surface of the water. According to Dr. Hollend, the petroleum springs of Zante are much in the same state as in the time of Herodotus. The principal pool is about 50 feet in circumference, and a few feet deep; the sides and bottom of this and the others are thickly covered with petroleum, which, by agitation, is brought to the surface of the water, and collected. The amount obtained is about 100 barrels annually.

The pitch lake of Trinidad is about three miles in circumference. The asphaltum is sufficiently hard in wet weather to support heavy weights, but during warm weather it is nearly fluid. It is intersected with numerous cracks filled with water, which sometimes close up, leaving marks on the surface. When highly covered with soil, as it is in many places, good crops of tropical productions are obtained; but, owing to this covering of soil, it is said to be difficult to ascertain the boundaries of the lake. Large quantities of naptha are obtained on the shores of the Caspian. The inhabitants of the town of Badbree, a port on that sea, are supplied with no other fuel than that obtained from the naptha and petroleum, with which the adjacent country abounds. The naptha springs at Rangoon, Pegu, produce over 92,000 tons per annum. Mr. Lyell supposes that bituminous minerals are produced from vegetable substances which have undergone certain transformations and chemical changes by the agency of subterraneous fire. "The bituminous shales," he remarks, "so common in geological formations of different ages, as also many stratified deposites of bitumen and pitch, seem clearly to attest that, at former periods, springs in various parts of the world were as commonly impregnated as now with bituminous matter, carried down, probably, by rivers into lakes and seas.

It will, indeed, be easy to show that a large portion of the finer particles and the more crystallized substances found in sedimentary rocks of different ages, are composed of the same elements as are now held in solution by springs, while the coarser materials bear an equally strong resemblance to the alluvial matter in the beds of existing torrents and rivers.

We have thus noticed the most important examples of the deposition of rocks from materials held in solution by various waters; but, when compared with the great geological formations which exist on the globe, they are relatively unimportant; though, as De la Beche observes, they teach us how such deposites may, chemically, have formerly taken place.

CHAPTER XVIII.

AGENTS WHICH FORM ROCKS (CONTINUED).

Igneous Causes.

Volcanic Action.—Definition.—Leibnitz's Theory.—Charles Darwin's Hypothesis.—Sir Humphrey Davy's Hypothesis.—Phenomena of Volcanic Eruptions.—Quantity of Ejected Matter.—Skaptar Jokul in Iceland.—Tomboro.—Submarine Volcanoes.—Graham Island.—Etna.—Vesuvius.—Pompeii.—Herculaneum.—Earthquakes.

Having considered somewhat in detail those changes which are wrought on the earth's surface by means of aqueous causes, we come now to contemplate such as have been produced by the agency of fire.

Volcanic action has been defined to be *the influence exerted by the heated interior of the earth on its external covering*. Under this definition, therefore, may be included all the subterranean phenomena, whether of volcanoes, or earthquakes, or those insensible movements of the land by which, as Mr. Lyell very plausibly supposes, large districts may be depressed or elevated without convulsions.

As we have already described the nature of volcanic products, it is unnecessary to allude to them at present; a few remarks, however, may not be out of place in relation to the different theories which have been formed for the explanation of volcanic phenomena.

The prevailing hypothesis in relation to volcanic action is that of Leibnitz, which is supported by Humboldt, Cordier, and, with some modifications, by Philips, and the most eminent geologists of the present day. This regards volcanic action as the necessary result of the influence exerted by the heated interior upon the cooled exterior masses of the globe. "If the earth," says Philips, "be now generally hot within, it must formerly have been hotter; in the process of cooling, the exterior solidified part and the interior fluid parts contract unequally, a general pressure and tension result, and the crust breaks locally to restore the equilibrium. Hence earthquakes and fissures, on some of which volcanic vents are established, which serve more or less to relieve the subterranean pressure, as earthquakes also do. If, in addition to this general view, we suppose the admission of water through fissures to particular parts of the 'ocean of melted rock,' it is easy to see that the observed mechanical phenomena of volcanoes and earthquakes will result as the effect of a local excitement superadded to a general operation." From extensive observa tions, Mr. C. Darwin maintains the existence of a vast internal sea of melted rock below a large part of South America, and regards the submarine outbursts, the renewed volcanic activity, and the permanent elevation of the land, as forming parts of one great action and effects of one great cause, multiplied only by local circumstances. From the phenomena of earthquakes he adduces the following conclusions, which Mr. Philips thinks ought to be adopted.

1st. That the primary shock of an earthquake is caused by a violent rending of the strata, which on the coast of Chili and Peru, seems generally to occur at the bottom of the neighbouring sea.

2d. That this is followed by many minor fractures, which, though extending upward, do not, except in submarine volcanoes, actually reach the surface.

3d. That the area thus fissured extends parallel, or nearly so, to the neighbouring coast mountains.

4th. That the earthquake relieves the subterranean force precisely in the same manner as an eruption through an ordinary volcano.

There is but one other theory in relation to volcanic action which deserves mention, and that is what has been termed "the chemical hypothesis." It was originally proposed by Sir Humphrey Davy, in consequence of his discovery of the metallic and metalloid bases of the alkalies and earths, which burn when brought in contact with water. Dr. Daubeny, who is now the chief supporter of this view, states that, when water is brought in contact with these metals, which are supposed to form the interior of the earth, one part of the liquid is decomposed, the metals and the chlorides will seize oxygen, and be thereby converted to silica, alumina, lime, magnesia, soda, &c., substances which predominate in lavas; the hydrogen will be liberated in the state of gas, or, in combination with chlorine, will form hydrochloric acid, which is known to be often present in the vaporous exhalations of volcanoes. He supposes that the heat generated by the primary chemical action (oxygenation) and the energetic action of steam, to which part of the water is converted, are sufficient to account for the mechanical phenomena of volcanoes.

It is unnecessary to state the numerous objections which have been raised to this theory, as it was abandoned by its projector, Davy, as he became better acquainted with the nature of these substances, to whose agency he had once attributed volcanic phenomena. It, however, still has its advocates; and Philips remarks, "it appears to us to be clear, that the union of the two speculations here brought into comparison is not only practicable, but reasonable, and even necessary. A general cause of *change of form* of the earth's surface and interior parts is supplied by the doctrine of a change in interior heat; abundant admission for water is afforded by the *fractures* necessary (upon this view) to adjust the balance of pressures; and the chemical products can only be properly understood by a suitable hypothesis of chemical action."*

Volcanic eruptions are usually preceded by detonations in the mountain and agitations of the earth, or earthquakes in the vicinity; after which the mountain vomits forth an abundance of ashes, cinders, and stones, and streams of melted lava flow from apertures made in the side of the cone, the resistance of which becomes unequal to the pressure of the melted mass within. The lava very rarely seems to proceed from the lip of the crater. Lava, when observed as near as possible to the point from whence it issues, is, for the most part, a semi-fluid mass of the consistence of honey, but sometimes so liquid as to penetrate the fibre of

* Treatise of Geology, vol. ii., p. 214.

wood. It soon cools externally, and therefore exhibits a rough, unequal surface; but, as it is a bad conductor of heat, the internal mass remains liquid long after the portion exposed to the air has become solidified. That of 1822, some days after it had been emitted, raised the thermometer from 59° to 95° at a distance of 12 feet; 3 feet off, the heat greatly exceeded that of boiling water. The temperature at which it continues fluid is considerable enough to melt glass and silver, and has been found to render a mass of lead fluid in 4 minutes, when the same mass placed on red-hot iron required double that time to enter into fusion. Even stones have been melted when thrown into the lava of Vesuvius and Ætna.*

Quantity of ejected Matter.—The greatest amount of volcanic matter ejected at any single eruption occurred in Iceland in 1783. This island, ever since the twelfth century, has been subject to a series of eruptions; and, during the whole period, there never has been an interval of more than 40, and rarely of more than 20 years, without an eruption or an earthquake. Some of these have lasted six years without ceasing. Earthquakes have often shaken the whole island at once, causing great changes in the interior, such as the sinking down of hills, the rending of mountains, the desertion by rivers of their channels, and the appearance of new lakes. New islands have been thrown up near the coast, some of which still exist, while others have disappeared either by subsidence or the action of the waves.

In June, 1783, the volcano *Skaptar Jokul*, in Iceland, commenced throwing out a torrent of lava, which, with slight interruptions, continued to flow for the space of two years, filling up rivers and lakes, overflowing and destroying villages, forming immense fiery cataracts from 12 to 15 miles wide

* Daubeny on Volcanoes.

and 100 feet deep, impregnating the air with noxious vapours, and causing an extensive famine, by depositing showers of ashes over the whole island, and driving away the fish from the shores. During this time it destroyed more than 20 villages, and 9000 human beings out of a population of 50,000. The lava flowed in nearly opposite directions; one current being 50, and the other 40 miles in length. The breadth of one was from 12 to 15 miles, that of the other about 9. The depth of both ranged from 100 to 600 feet. In 1737, the current of lava from Vesuvius, which destroyed Torre del Greco and ran into the sea, is supposed to have accumulated more than 33,000,000 cubic feet; and in 1794, another current was calculated to exceed 46,000,000 feet. Mount Ætna, which rises above 10,000 feet in height, and embraces a circumference of 180 miles, is composed entirely of lavas, which appear to have been emitted above the surface of the water, and not under pressure. Some of the streams of lava which have issued from it are 15 or 20 miles in length, 4 or 5 broad, and from 50 to 100 feet in thickness. The great current which destroyed Catania is estimated to contain 93,000,000 cubic feet. This occurred in the year 1669. An earthquake levelled to the ground all the houses in Nicolosi, a town situated 20 miles from the summit of Ætna, and ten from the sea. Two gulfs then opened near that town, from whence sand and scoria were thrown out in such quantity, that in the course of three or four months a double cone was formed, called *Monti Rossi*, 450 feet high. In the plain of St. Leo a fissure also opened, with a loud crash, of an unknown depth, and ran in a tortuous course, 12 miles in length, to within a mile of the summit of Ætna, giving out a most vivid light. Five other parallel fissures of considerable length afterward opened, and emitted smoke, and gave out bellowing sounds, which were heard at a distance of 40 miles

After overflowing 14 towns and villages, some of them having a population of between 3000 and 4000 inhabitants, the lava at length arrived at the walls of Catania. These had been raised on purpose to protect the city; but the burning flood accumulated till it rose to the top of the rampart, which was 60 feet in height, and then it fell in a fiery cascade and overwhelmed part of the city. Excavations still show the wall standing, and the lava curling over it as if in the very act of falling. After coursing 15 miles farther, it entered the sea in a stream 600 yards broad and 40 feet deep. While moving on, Ferrara describes its surface as appearing like a mass of solid rock, and its mode of advancement was by the occasional cracking or fissuring of the solid walls. A gentleman of Catania, desiring to secure the city from the approach of the threatening torrent, went out with a party of 50 men, armed with iron hooks and crows. They broke open one of the solid walls which flanked the current, and immediately there issued forth a stream of melted matter, which took the direction of Palermo; but the inhabitants of that town, being alarmed for their safety, took up arms and put a stop to farther operations.

As a farther illustration of the solidity of the walls of an advancing lava stream, Recupero states that, in the year 1766, while standing on a small hill to behold the slow and gradual approach of a lava current two miles and a half broad, two small threads of liquid matter, issuing from a crevice, detached themselves from the main stream and ran rapidly towards the hill. He and his guide had just time to escape, when they saw the hill, which was 50 feet high, surrounded, and in fifteen minutes melted down into the burning mass so as to flow on with it.

In the year 1538, the town of Tripergola, near Puzzuoli, was destroyed by an eruption, which threw up the hill called Monte Nuovo upon its site. After no less than 20 shocks of an earthquake, which occurred in the space of 24 hours, a large fissure approached the town, with a tremendous noise and with the emission of flame, and began to discharge mud, composed of pumice-stones and ashes mixed with water, with some blocks of solid stone. The ashes, by which the town was entirely overwhelmed, fell in immense quantities even at Naples, while the neighbouring town of Puzzuoli was deserted by its inhabitants. The sea suddenly retired 200 yards, and a portion of its bed was left dry. The whole coast from Monte Nuovo to beyond Puzzuoli was at that time upraised to the height of many feet above the bed of the Mediterranean, and has ever since permanently remained elevated. The hill, which was thrown up in a day and a night, was 440 feet high above the level of the bay, and its base nearly a mile and a half in circumference. The depth of the crater is supposed to be 421 feet from the summit of the hill, so that its bottom is only 19 feet above the level of the sea.

Sir Stamford Raffles gives the following account of a volcanic eruption from Tomboro, on the island of Sumbawa: "The first explosions were heard at various distant places, where they were generally mistaken for discharges of artillery. They commenced on the 5th and continued till the 18th of April, when the eruptions became more violent; and such a great discharge of ashes took place that the day was obscured, and darkness prevailed over considerable distances. A Malay prow, which was at sea, at a great distance from the island, was on the 11th enveloped in utter darkness; and afterward, while passing the island, the commander observed that the lower part appeared in flames, while the upper portion was concealed in clouds. Upon landing for the purpose of procuring water, he found the ground covered to the depth of three feet by ashes, and several large prows thrown on shore by the concussion of the sea. Quitting Sumbawa, he with difficulty sailed through a quantity of these ashes floating on the sea, which he described as two feet thick and several miles in extent." The captain of a British vessel, cruising at a considerable distance from the island, thus describes the scene: "At the commencement of the explosions, they so closely resembled those of cannon that it was supposed there was an engagement of pirates somewhere in the neighbourhood. Troops were consequently embarked on board the Benares, and the vessel stood out to sea in search of the supposed pirates. On the morning of the 12th, the face of the heavens to the southward and westward had assumed a dark aspect, and it was much darker than when the sun rose. As it came nearer it assumed a dusky red appearance, and spread over every part of the heavens; by ten it was so dark that a ship could hardly be seen a mile distant; by eleven the whole of the heavens was obscured, except a small space towards the horizon to the eastward, the quarter from which the wind came. The ashes now began to fall in showers, and the appearance was altogether truly awful and alarming. By noon the light that remained in the eastern part of the horizon disappeared, and complete darkness covered the face of day. This continued so profound during the day, that it was impossible to see the hand when held close to the eyes.

"The ashes fell without intermission during the night, and were so light and subtile that, notwithstanding the precautions of spreading awnings fore and aft as much as possible, they pervaded every part of the ship. When daylight returned every part of the ship was found covered with the falling matter, which had the appearance of calcined pumice-stone, and nearly the colour of wood ashes. It lay in heaps of a foot in depth on many parts of the deck, and several tons' weight of it must have been thrown overboard; for, though an impalpable powder when it fell. when compressed it had considerable weight, a pint measure of it weighing twelve ounces and three quarters."

During this eruption many thousand inhabitants were destroyed; vegetation was completely killed; the sea rose twelve feet higher than it was ever known to do before, and violent whirlwinds prostrated everything before them.

In May, 1759, the plain on which the volcano of Jorulla now stands was highly cultivated, and covered with indigo and sugar-canes. In June following, hollow subterranean noises were heard, accompanied by earthquakes, which lasted fifty or sixty days. By the month of September tranquillity seemed established, but on the 28th and 29th of this month the subterranean noises again began, and the ground, over an area of three or four square miles, according to Humboldt, rose up like a bladder to a height of 524 feet towards the centre of the present volcanic district. Fragments of rock were thrown to a great height; ashes were scattered far and wide; and the light emitted was seen at a great distance. Two streams of water which ran through the plain precipitated themselves into the volcanic vent, and assisted, by the decomposition of their waters, the fury of the eruption.

Submarine Volcanoes.—The whole of Iceland is believed to be a volcanic mass which has been projected from beneath the ocean. In January, 1783, a volcanic eruption, attended with flame, rose through the sea about thirty miles from Iceland; several islands were formed, and a reef of rocks now exists where they were formerly situated. The flame lasted several months, during which vast quantities of pumice and light slags were washed on shore. Another submarine eruption occurred near the same island in June, 1830, which resulted in the formation of an island

In the year 1811, the island of Sabinæ was thrown up off St. Michael's, in the Azores. It was 300 feet high, with a crater in the centre, but was soon entirely washed away by the waves.

One of the most recent instances of the forma-

Fig. 41.

Graham Island as seen on the 18th of July 1831 tion of a volcanic island was in 1831, between Sicily and the coast of Africa. About the 10th of July, the captain of a Sicilian vessel reported that, as he passed near the place, he saw a column of water like a water-spout, 60 feet high and 800 yards in circumference, rising from the sea, and soon afterward a dense steam in its place, which ascended to the height of 1800 feet. On his return on the 18th of July, he found a small island twelve feet high, with a crater in its centre, ejecting volcanic matter and immense volumes of vapour, the sea around being covered with floating cinders and dead fish. The eruption continued with great violence to the end of the month, when it was from fifty to ninety feet high, and three fourths of a mile in circumference.

By the 4th of August it became above 200 feet high and 3 miles in circumference, and presented an appearance as in the following cut.

Fig. 42.

Graham Island as seen 1st of August.

From this time it rapidly diminished in size by the action of the waves, and on the 25th of August was only two miles in circumference, and on the 3d of September three fifths of a mile round and 107 feet high, with a crater 780 feet in circumference. On the 29th of September its circumference was reduced to about 700 yards, and was composed of incoherent ejected matter, scoriæ, pumice, &c., forming regular strata. Towards the close of October no vestige of the crater remained, and the island was nearly levelled with the surface of the ocean, except in one place, where there was a small sandbank. At present there is a dangerous reef of volcanic rocks, about ten feet under water, where the island formerly stood.

Ætna.—The eruptions of Ætna date back among the earliest records of history. The first on record is in the year 480 before Christ. This was followed by others, 427 and 396 B.C. Then, after a lapse of 250 years, we have four more, between 140 and 122 B.C. Then, after 66 years of rest, we have three others, between 56 and 38 B.C. Seventy-eight years then elapse before another, in the year 40 A.D. A pause till 251 A.D. Another till 812 A.D. A third to 1169 A.D. Since then, in the 12th and 13th centuries, we have had 3 eruptions; in the 14th, 2; in the 15th, 4; in the 16th, 3; in the 17th, 8; in the 18th, 14; in the 19th, 6 eruptions. The number of eruptions in Iceland during the last nine centuries is 42.*

Vesuvius.—At the time of Strabo, Vesuvius offered no other indications of its volcanic character than might be inferred from the analogy of its structure to other volcanoes. The ancient cone was of a very irregular form, terminating with a flattish summit, where the remains of an ancient crater, nearly filled up, had left a slight depression, covered in its exte-

* Daubeny on Volcanoes.

rior with wild vines, with a barren plain at the bottom. On the exterior, the flanks of the mountains were clothed with fertile fields, richly cultivated, and at its base were the populous cities of Herculaneum and Pompeii. In the year 63 after Christ, there was an earthquake which did some injury to the cities in its vicinity. From that time to the year 77, slight shocks were experienced, and in August of that year a tremendous explosion took place, in which the elder Pliny lost his life. It appears that he commanded at that time the Roman fleet, which was stationed at Misenum, and in his anxiety to obtain a near view of the phenomena, he was suffocated by sulphureous vapours. The younger Pliny, his nephew, gives a very vivid description of the scene in one of his letters. He represents a dense column of vapour as first seen rising vertically from Vesuvius, and then spreading itself out laterally, so that its upper portion resembled the head, and its lower the trunk of the pine. This black cloud was occasionally pierced by flashes of fire, as vivid as lightning, preceded by darkness more profound than night. Ashes fell even upon the ships at Misenum, and caused a shoal in one part of the sea; the ground rocked, and the sea receded from the shores, so that marine animals were seen on the dry sand.

It is a remarkable fact, that neither Pliny, nor Tacitus, nor Suetonius should allude to the destruction of Herculaneum and Pompeii, which were overwhelmed during this eruption, and that the first historian who mentions them is Dion Cassius, who flourished 150 years after Pliny. He states "that during the eruption a multitude of men of superhuman stature, resembling giants, appeared sometimes on the mountain and sometimes in the environs; that stones and smoke were thrown out, the sun was hidden, and then the giants seemed to rise again, while the sound of trumpets were heard," &c.;

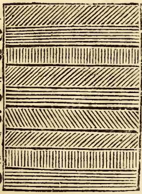
and finally, he states, "two entire cities, Herculaneum and Pompeii, were buried under showers of ashes, while all the people were sitting in the theatre."

Mr. Lyell thinks that there is no evidence to prove that any lava flowed from Vesuvius in 79, and that the ejected substances which overwhelmed Pompeii were lapilli, sand, and fragments of molten lava, as when Monte Nuovo was thrown up in 1538. From the excavations which have been made, it is certain that none of the inhabitants perished in the theatres, and that but very few perished at all.

It appears, from an examination made by Mr. Lyell in 1828, that the city of Pompeii was covered with numerous alternations of different horizontal beds of tuff and lapilli,* for the most part thin, and subdivided into very thin layers.

The following is a section:

Fig. 43.



		Ft.	In.
1	Black sparkling sand - -	0	2
2	Vegetable mould - - -	3	0
3	Brown incoherent tuff - -	1	6
4	Small scoriæ and white lapilli* -	0	3
5	Brown earthy tuff - - -	0	9
6	Do. with lapilli in layers -	4	0
7	Layer of whitish lapilli - -	0	1
8	Gray solid tuff - - -	0	3
9	Pumice and white lapilli - -	0	3

The depth of the bed of ashes above the houses is variable, but seldom exceeds 12 or 14 feet. Nos. 3 and 5 of the above strata were filled with small prismatic globules. Mr. Scrope saw these formed in great numbers in 1822, by rain falling during a volcanic eruption on fine volcanic sand; and he also states that they are produced like hail in the air, by the mutual attraction of the finest particles of damp

* Small volcanic cinders, little stones.

sand. We think it may be admitted, then, as an established fact, that no stream of lava has ever reached Pompeii since it was first built, although the town was built upon a lava foundation.

At Herculaneum, Mr. Lyell thinks the case is different; although the substance which fills the interior of the houses and the vaults must have been introduced in the state of mud, yet the superincumbent mass differs both in composition and thickness. As Herculaneum was situated several miles nearer to the volcanoes, it was, of course, more exposed to be covered, not only by showers of ashes, but by alluviums and streams of lava. Accordingly, masses of both have accumulated on each other above the city, to a depth of nowhere less than 70, and in many places of 112 feet. The tuff which envelops the buildings consists of pumice mixed with comminuted volcanic ashes.

Herculaneum was discovered in 1713 by the accidental circumstance of sinking a well, which came right down upon the theatre, where the statues of Hercules and Cleopatra were found. No buildings but this are open to inspection, as the Forum, Temple of Jupiter, and other buildings have been filled up with rubbish as the workmen proceeded, owing to the difficulty of removing it from so great a depth below ground. "Both at Herculaneum and Pompeii," says Lyell, "temples have been found with inscriptions commemorating the rebuilding of the edifices after they had been thrown down by an earthquake, which happened in the reign of Nero, sixteen years before the cities were overwhelmed. In Pompeii, one fourth of which is now laid open to the day, both the public and private buildings bear testimony to the catastrophe. The walls are rent, and in many places traversed by fissures still open. Columns are lying on the ground only half hewn from huge blocks of travertin, and the temple for which they are designed is near half repaired. In some few places the pavement had sunk in, but in general it was undisturbed, consisting of large, irregular flags of lava joined neatly together, in which the carriage-wheels have often worn ruts an inch and a half deep. In the wide streets, the ruts are numerous and irregular; in the narrower, there are only two, one on each side, which are very conspicuous. It is impossible not to look with some interest even on these ruts, which were worn by chariot-wheels more than seventeen centuries ago; and, independently of their antiquity, it is remarkable to see such deep incisions so continuous in a stone of great hardness. We observe nothing of the kind in the oldest pavements of modern cities."

It seems that the inhabitants not only had time to escape, but also to take most of their effects with them. The skeletons of two soldiers were found in the barracks at Pompeii, chained to the stocks, and in the vaults of a country house in the suburbs were the skeletons of seventeen persons, who probably fled there to escape the shower of ashes. They were found enclosed in an indurated *tuff*, and in this matrix was preserved a perfect cast of a woman with an infant in her arms. Nothing but the skeleton remained. Around the neck a chain of gold was suspended, and on the bones of the fingers were rings, with jewels. A long row of earthen amphoræ was ranged along the sides of the same vault.

The writings scribbled by the soldiers on the walls of their barracks, and the names of the owners of each house, written over the doors, are still perfectly legible. The colours of fresco-paintings on the stuccoed walls in the interior of buildings are almost as vivid as if they were just finished. There were discovered public fountains decorated with shells; also a large collection of shells, belonging probably to a naturalist; abundance of fish-ing-nets; linen, with the texture perfect; vessels full of almonds, chestnuts, walnuts, &c.; also loaves of bread, with the baker's name stamped on them; a jar containing medicinal herbs; moist olives in glass cases; *caviare*, or roe of a fish, in a fine state of preservation: *boxes of pills* on the counter of an apothecary; and, lastly, an abundance of *papyri* or manuscripts, mostly written in Greek.

Earthquakes.—We have only space for a brief notice of the phenomena connected with earthquakes; but as they are the result of the same causes which occasion volcanic action, it is proper to notice them more in detail than we shall be able to do. We have already seen that earthquakes are most frequent and violent in volcanic districts and countries immediately adjacent; indeed, they may be said to form an inseparable attendant upon volcanic excitements, though they often happen where volcanic fires are dormant or extinct. "It is in volcanic countries," says Philips, "that proofs have been found of the real displacement and positive elevation of land on particular days and during particular earthquakes; while, at points far remote from Vesuvius and Hecla, the land is slowly rising in Scandinavia; perhaps slowly sinking in Greenland; perhaps alternately elevated and depressed on some parts of the shores of Britain."

In the year 1822, the Chilian coast (South America) for the space of 1200 miles was agitated by a convulsive movement, and elevated, for the distance of 100 miles, from two to seven feet; the shock of the earthquake having extended over an area of 100,000 square miles. In 1835, another shock was experienced on the same coast, attended with an eruption of the volcanic cones on the Andes. An enormous wave, 28 feet high, destroyed Talcaguano; columns of smoke rose in the sea, followed by whirlwinds, and the land was elevated in different places from one to ten feet!

"In order," says Mr. Lyell, "to give some idea of the enormous amount of change which this convulsion may have occasioned, let us assume that the extent of country moved was correctly estimated at 100,000 square miles; an extent just equal to half the area of France, or about five sixths of the area of Great Britain and Ireland. If we suppose the elevation to have been only three feet, on an average, it will be seen that the mass of rock added to the continent of America by the movement, or, in other words, the mass previously below the level of the sea, and, after the shocks, permanently above it, must have contained 57 cubic miles in bulk (or about as high as Ætna), with a circumference at the base of nearly 33 miles." Mr. Lyell calculates that the mass of rock elevated must have been, if two miles thick, 200,000 cubic miles in length, and have exceeded in weight 363 million of the great pyramids of Egypt.

In the year 1819 a violent earthquake was experienced at Cutch, in the Delta of the Indus, which caused the sea to rush in by the Eastern mouth of the Indus, and convert a tract of land 2000 square miles in area into an inland sea. At the same time, also, a tract of country 50 miles in length and 16 in breadth was elevated 10 feet, comprising an area of 7000 square miles, equal to about one fourth of Ireland.

The motion of the ground produced by earthquakes is not always the same; sometimes resembling the undulating motion of a heavy swell at sea, though much quicker, and being at others tremulous, as if some force shook the earth violently in one spot. The former of these is far more dangerous, as it forces walls and buildings off their centres of gravity, crushing whatever may be beneath them.

Earthquakes not only cause an elevation, but also a subsidence of the land. Thus, in the year 541, Pompeiopolis was swallowed up; in 867, Mount

Acraus fell into the sea; in 1112, the city of Liege was flooded by the Meuse; in 1186, a city on the Adriatic shore sank into the sea; in 1596, the sea covered many towns in Japan; in 1638, St. Euphemia became a lake; in 1692, Port Royal sank; and in 1755, the great earthquake caused the new quay at Lisbon to sink, and its place was occupied by water 100 fathoms deep; and many places on the Portuguese and African shores were ingulfed. We have already stated that in 1819 a town and large tract of country at the mouth of the Indus were submersed.

De la Beche remarks, "that the changes caused by earthquakes on the surface of the earth are small, and quite irreconcilable with those theories which propose to account for the elevations of vast mountain ranges, and for enormous and sudden dislocations of strata, by repeated earthquakes acting invariably in the same line, thus raising the mountains by successive starts of five or ten feet at a time, or by catastrophes of no greater importance than a modern earthquake. It is useless to appeal to time; time can effect no more than its powers are capable of performing; if a mouse be harnessed to a large piece of ordnance, it will never move it, even if centuries on centuries be allowed; but, attach the necessary force, and the resistance is overcome in a minute."

Whether this opinion or that of Mr. Lyell is the most probable, we shall not attempt to decide

PART II.

CHAPTER XIX.

DESCRIPTIVE GEOLOGY.

PHYSICAL GEOGRAPHY OF NORTH AMERICA.

Extent of North America.—Mountains.—Rocky Mountains.—Atlantic Series.—The Blue Ridge.—The Appalachian.—The Alleghany.—The Eastern System.—Atlantic Plain.—Central Basin.—Influence of Geological Structure on Society.—Influence of Geological Formations on Scenery.

Physical Geography.—Before treating of the geology of this country, which our limits will only allow us to do in a very brief and cursory manner, it will be proper to notice some of its grand geographical features; and, in doing so, we shall not confine our attention to the United States, but embrace the whole of North America. This extends through twenty-nine degrees of latitude and fifty-eight of longitude, comprising a superficial area of 2,300,000 square miles, and having a frontier line of 10,000 miles in length, 3600 of which are seacoast and 1200 lakecoast; and a line drawn from the Pacific to the Atlantic, in its widest part, would be more than 2500 miles long. The portion at present organized into state governments comprises an area of 1,300,000 square miles.

North America* is traversed by two great mount-

* For much of the following chapter we are indebted to the American edition of the "Encyclopedia of Geography," published in Philadelphia, and the best work of the kind that has ever appeared.

ain ranges, which divide the country into three distinct natural sections. These may be called the Atlantic Slope, the Mississippi Valley, and the Pacific Slope. The Alleghany or Appalachian range is remarkable chiefly for its length, extending from Canada on the north to Alabama on the south, a distance of more than 1200 miles; while its mean average height is not more than 2500 feet, and more than half of this consists of the height of the mountain ridges above their bases, and the other, of the height of the adjoining country above the sea. About midway between the Atlantic and the Mississippi lies a vast table-land, extending from the rivers of Alabama and Mississippi to the great lakes and the St. Lawrence, occupying the western part of the Atlantic states, and the eastern part of the adjoining states of the Mississippi Valley. Along this table-land extend five or six parallel mountain chains, of which the most remarkable are the Blue Ridge, the Alleghany Ridge, the Wickany, and the Cumberland Mountains. The White Mountains of New-Hampshire, which are usually considered as a prolongation of the Blue Ridge, contain some of the loftiest summits east of the Mississippi, Mount Washington being 6428 feet above the sea; the Black Mountain, in North Carolina, which is in the range of the Blue Ridge, is ascertained to be 6476 feet in height, while the highest point of the Alleghany is not over 3000 feet above the sea.

The Rocky Mountains have been sometimes called the Andes of North America, or the Chippewayan system; and they extend from the Isthmus of Panama, parallel with the Pacific, almost to the Arctic Sea; having an average height of 8000 feet above the ocean, or 5000 above the level of their base. Their highest summit has usually been computed at about 12,000 feet; though Professor

* Outlines of Geology, p. 13.

Renwick gives the height of Mount St. Elias, on the northwest coast, as 18,000; and Mount Fairweather, in the same region, as 14,913 feet above the ocean.

These different mountain ranges thus may be grouped under two divisions, the *Atlantic* and the *Pacific Series.* The Atlantic series may be divided into the *Eastern*, the *Blue Ridge*, the *Appalachian*, and the *Alleghany Systems.* The *Eastern System* will comprehend all the mountain ranges of New-England, with their prolongation, the Highlands, which cross the Hudson at West Point, and pass through New-Jersey into Pennsylvania. The *Blue Ridge System* will embrace that long range of swelling and lofty ridges which extends from Maryland to Alabama, and known in Virginia as the Blue Ridge. The *Appalachian System* is made up of a number of nearly parallel ridges, of very steep sides, and remarkably level outline along their summit, having an elevation rarely exceeding 2000 feet above their included valleys. Commencing west of the Hudson, they pursue a southwest course parallel to the Highlands as far as these extend, and beyond that, parallel to the Blue Ridge system as far as Alabama.

Immediately west lies the *Alleghany System*, which also extends to the northwest of the Appalachians, and is made up of several mountains, which rise from an elevated table-land, presenting little uniformity in their course, except that their ridges are usually parallel to those of the former system. The eastern limits of the Alleghany system will then embrace the so-called Alleghany Mountains of Pennsylvania, the Eastern Front-Ridge, the Green Brier Mountains, Great Flat-top Mountains of Virginia, and others in Tennessee.

At present it will suffice to remark, that the eastern system of mountains, as well as the Chippewayan, consist almost entirely of *primary rocks*, chiefly of the stratified class. The Blue Ridge system is composed of rocks of the *transition* class, or the oldest formations of the non-fossiliferous secondary group. The Appalachian belt consists of *secondary* rocks of the oldest kind, containing fossils, but no rocks as recent, apparently, as the bituminous coal series. The Alleghany range is composed also of *secondary* formations, which seem to owe their configuration, which is that of vast piles of nearly horizontal strata, rising from a plain intersected by innumerable deep valleys of denudation, to causes which seem to have removed part of the high plateau on which they stand, rather than to direct uplifting forces, such as appear to have elevated the more irregular and convulsed systems of the other three mountain systems.

Thus nearly the whole of North America is divided into two immense plains, the one lying between the Atlantic and the Appalachian or Alleghany Mountains, and extending from Long Island to the Gulf of Mexico; the other, which may be called the central basin of the continent, from the Alleghanies to the Rocky Mountains, and expanding from the Gulf of Mexico, widening as it stretches northward until it reaches the Arctic Sea and Hudson's Bay. The first great plain, extending from the Atlantic to the adjacent mountains, is, in the Southern states, nearly 200 miles in breadth, and throughout its whole extent it is separated into two tracts, strongly contrasted with each other both as respects their geographical and geological features. The boundary which divides them is the eastern edge of a low, undulating line of primary rocks, which, forming the termination of the upper or rocky tract, separates it from the lower flat and sandy plains, with every appearance of having been at one time the line of the coast.

From New-Jersey to North Carolina, this boundary, beginning the rocky country, presents a well-marked barrier to the tide in nearly all the rivers that cross from the mountains to the sea. Over this rocky boundary, the rivers which descend from the mountains over the western tract precipitate themselves, either in falls or long rapids, and emerge into the tide level to assume at once a totally new character. South of North Carolina, this line of primary rocks leaves the tide and retires much nearer to the mountains, though it still preserves its general features, separating the rolling and picturesque region of the older rocks from the tertiary plains next the ocean; and, though its base is not any longer laved by the tide, as in Virginia, Maryland, and Pennsylvania, it still produces rapids and cataracts in the southern rivers which cross it. Ranging for so very great a distance with a remarkable uniformity of outline and height, on an average between 300 and 400 feet above the tide, it constitutes an admirable geographical as well as commercial limit. Several of the chief cities of the Atlantic States stand upon this boundary, from the obvious motive of seeking the head of navigation. The upper tract, which has been called the *Atlantic Slope*, possesses a very variable width, being narrow in the New-England states and in New-York, where the mountains approach the coast, but expanded in Virginia and the Carolinas, where it has a breadth of about 200 miles, ascending from the tide-waters in an undulating, hilly surface, to a mean elevation of about 500 feet near the mountains. As it approaches these, its hills swell into bolder dimensions, till we gain the foot of the Blue Ridge, or first chain of mountains. This tract then consists almost exclusively of the older sedimentary and stratified primary rocks, such as gneiss, mica slate, &c. It forms a fine hilly country, exhibiting a marked uniformity in the direction of its ridges and valleys, running very generally northwest and southwest, or parallel with the mountains. The ridges, though not high, are long, and the fertile intervening val leys very extensive. It embraces a variety of fine soils, and immense water-power in its rivers and running streams. The tract lying between this and the Atlantic is low and monotonous in its aspect, having an average width of from 100 to 150 miles, and an elevation of about 100 feet. This has been called the *Atlantic Plain* of the United States, and we shall so designate it.

Professor Rogers remarks, that "the surface of this plain is everywhere scooped down from the general level to that of the tide by a multiplicity of valleys and ravines, the larger of which receive innumerable inlets and creeks, while the smaller contains marshes and alluvial meadows. The whole aspect of the barrier of primary rocks forming the western limits of this plain, forcibly suggests the idea that at a rather lower level they once formed the Atlantic shore, and that they exposed a long line of cliffs and hills of gneiss to the fury of the ocean; a survey of the plain just described* as strongly suggests the idea that all of it has been lifted from beneath the waves by a submarine force, and its surface cut into the valleys and troughs it presents by the retreat of the upheaved waters." This tract embraces a large proportion of the newer secondary and tertiary formations hitherto investigated upon this continent, and we are better acquainted with its organic remains than almost any other region, not only from the extensive denudation of its surface, but from the circumstance that its horizontal strata are admirably exposed in the deep cuttings and vertical banks of its rivers, often through many miles in extent.

The great central basin of North America spreads from the Alleghanies to the Rocky Mountains, and from the Gulf of Mexico to Hudson's Bay. It is

* Report on the Geology of North America, at the fourth meeting of the British Association for the Advancement of Science.

made up of a few wide and regular slopes; one from the Appalachians westward to the Mississippi; another, more uniform and far more extensive, from the Rocky Mountains to the Mississippi; and a third from the sources of the Mississippi and the great lakes north to the Arctic Sea. A very remarkable feature of this region is the great uniformity of the whole surface, and the regular and gentle ascent from the Gulf of Mexico to the head-waters of the Mississippi, reaching in that space an elevation of not more than 1000 or 1200 feet, and again ascending in a similar manner from the banks of the Mississippi to the foot of the Rocky Mountains. Between the Alleghanies and the Mississippi the surface is broken into hills, and embraces the most fertile territory in the United States. About 400 miles west of the Mississippi a barren desert commences, which extends back to the Rocky Mountains, covering a breadth of between 400 and 500 miles, and from Missouri, in latitude 56°, to Mexico.

Influence of the Geological Structure of the United States upon its Inhabitants.—Professor Silliman remarks,* that "it is perfectly apparent to geologists that the scenery of a country is not more exactly stamped by its geological formations than are the manners and employments of its inhabitants. The bleak hills and long winters of *New-England* are unfavourable to the most extensive and profitable agricultural pursuits, while the extensive and deeply-indented seacoasts, abounding with harbours, headlands, rivers, and inlets, naturally produce an impulse towards the ocean, which, conspiring with the original adventurous character of the population, sends them roving from the Arctic to the Antarctic Circle, till the wide world is laid under contribution by their enterprise. Their numerous streams and water-falls furnish the cheapest means for moving

* Appendix to Bakewell's Geology, p. 483.

machinery, and thus manufactories spring up wherever, in their expressive phraseology, there is *water-power;* and steam supplies local deficiencies of moving force. Ingenuity, conspiring with a general system of education, is excited under such culture to produce numerous inventions, and hosts of young men seek their fortunes successfully abroad as mechanics, seamen, traders, instructers, and politicians, who thus act powerfully, and, we trust, beneficially on other communities.

"The immense tracts of rich alluvium in the *Southern States*, the mildness of the climate, the coasts less abounding with safe inlets, and often modified by the action of the existing ocean, with a population not originally commercial, give a decided impulse to a vast agriculture, and a few great staples form the chief reliance of the landholders. It is easy to see that this state of things grows out of the recent secondary, the tertiary, and the alluvial formations, which constitute the ocean barrier from Staten Island to Florida, and from Florida to Texas, extending inland towards the mountains. In the West, the boundless fertile prairies and other tracts of productive soil conspire, with remoteness from the ocean, to indicate agriculture and pasturage as the main employment of the inhabitants, while exhaustless beds of coal, limestone, plaster of Paris, and rich deposites of lead and copper, and salt fountains both numerous and copious, furnish means for a manufacturing, as well as an agricultural population. These pursuits occupy the greater number of the people, while many find a profitable employment in navigating those immense inland seas, the great lakes, and the vast rivers, which run thousands of miles before they mingle with the ocean.

"What geologist fails to perceive that this state of things is the result of the immense lower secondary and transition formations which cover the Western States, sustaining portions of tertiary and, like all countries, alluvial depositions. While New England produces granite, marble, and other building materials of excellent quality, Pennsylvania, with the Western, and several of the Southern and Southwestern states, supplies inexhaustible magazines of coal, to prompt and sustain the manufacturing interests of this wide country, and to aid its astonishing navigation by steam, already of unexampled extent on its internal waters, and destined at no distant day to compete on the main ocean in amicable rivalry with our parent country." The following remarks of Professor Hitchcock are based upon the same established truths, that the character of a people is affected by the geological structure of the country. "Some may contend that it is more important to transfer the New-England character to the unsettled West, thus to multiply our numbers and wealth at home. But the history of the world leads us to fear that the New-England character cannot long be preserved except upon New-England soil, or upon a soil that requires great industry for its cultivation. Place New-England men where the earth yields spontaneously, and the locks of their strength will soon be shorn. If we look over the map of the world and the history of the past, we shall find, as a general fact, that the brightest exhibitions of human character have been made in regions where nature has done less, but art and industry more. If, therefore, we wish to increase the moral power of New-England, it must be done by improving her soil, and increasing her resources and population. If these views are correct, which, I acknowledge, do not fall in with the prevailing notions, they furnish a new stimulus for vigorous effort in the improvement of our soils."* The truth of these

* Hitchcock's "Report on a Re-examination of the Economical Geology of Massachusetts." It might, perhaps, be objected to his view of the subject, that if improving the soil increases the "moral power" of a people, then where the soil is the rich-

remarks is too self-evident to need support; for it is a matter of daily observation, that, other things being equal, such individuals of any given population who live by labour requiring constant skill, ingenuity, and judgment, will exhibit far greater powers of reasoning and thought, and will, in fact, be in every respect mentally superior to those who merely follow some routine occupation that requires no exercise of the rational faculties. De la Beche, speaking of the inhabitants of Cornwall, in England, remarks, "The variation in the mental condition of the people in this district is remarkably striking. This variation is, no doubt, due to many local causes, but among them the *geological structure of the country* would appear to hold a more important place than might at first sight, perhaps, be anticipated. The chief contrast would probably be found between the labourers on the poor lands of the carbonaceous series of northwestern Devon and the miners of Cornwall, both considered in the mass. While the former are thinly distributed over the country, full of prejudices against improvement, and still often firm believers in witchcraft, ghosts, &c., the miners are thickly congregated in the neighbourhood of the working beds, abound with intelligence, and, *from the constant exercise of their judgment*, upon which, indeed, the living of a large population entirely depends, able to take correct and enlarged views of many other subjects than those immediately connected with their ordinary occupations. The miners, nevertheless, in Cornwall and Devon, labour under considerable disadvantages as regards education, when compared with those of many other countries, where mining colleges or schools are founded. But the necessity of studying the varying condition of their lodes has, nevertheless, so

est *there* must be the greatest moral power. It is the *manual labour* required in the one case, and not the other, which makes all the difference.

accustomed their minds to the habit of reasoning, that they certainly, as a mass, greatly exceed in intelligence the other labouring population of the district, which, with the exception of the fishermen and the sailors, is chiefly agriculture," &c.*

Influence of the Geological Structure of the United States on its Scenery.

That the peculiar scenery of any country is dependant on its geological formation, is too evident to need remark. Thus, in an *alluvial* or *tertiary* district, we expect to see the face of the country level and monotonous; in a *secondary* region we look for a surface, if not uniformly level, yet not characterized by lofty hills or abrupt mountains; in a *transition* country we look for a surface of great irregularity, now swelling into lofty hills and moderately elevated mountains, traversed by frequent valleys and gentle slopes, combining great variety and beauty in its scenery; as among the table-land of the Alleghanies and the Blue Ridge. In a *primitive* region we expect to see abrupt and lofty mountains; the strata thrown into every degree of elevation and the greatest confusion; sharp towering peaks; craggy and overhanging cliffs; roaring torrents; all that is wild, and rugged, and sublime, meet the eye and challenge admiration! Owing to the variety of geological structure, no country in the world presents a more varied scenery than our own. No valleys on the face of the globe exceed in fertility and beauty those of the Housatonic, Connecticut, the Susquehanna, the Ohio, and the Mississippi. No villages ever built by man combine in their location greater advantages and beauties than those of Springfield, Northampton, Amherst, Pittsfield, Stockbridge, Sheffield, and numerous others which sprinkle and adorn the

* Geological Report on Cornwall, Devon, &c., p. 462.

Connecticut and Housatonic valleys. None ever contained a more enlightened, moral, industrious, free, and happy population. For beauty and variety, if not sublimity of scenery, New-England may challenge competition with the world. Everywhere broken and diversified, now presenting green and cultivated slopes to the sight, now throwing its granite pillars nearly 7000 feet into the sky,* wrapped in hoary clouds for ten months of the year, or covered with a mantle of snow; now presenting abrupt precipices, fantastic hills, deep gorges, yawning chasms, and verdant valleys; everywhere alive with an active and intelligent population, converting its stony declivities into fruitful cultivated fields, its mountains of granite and marble into polished building stones, and its rich mineral treasures, inexhaustible sources of wealth, into various products which minister to the necessities and comforts of man. There, too, we may say, "*steam* is on the rivers, and the boatman may repose on his oars; it is on the highway, and begins to exert itself along the courses of land conveyances; it is at the bottoms of mines a thousand feet below the earth's surface; it is in the mill, and in the workshops of the trades. It rows, it pumps, it excavates, it carries, it draws, it lifts, it hammers, it spins, it weaves, it prints."†

* The White Mountains of New-Hampshire.
† Daniel Webster.

CHAPTER XX.

GEOLOGY OF THE UNITED STATES.

PRIMARY ROCKS OF THE UNITED STATES.

Primitive Rocks—Prof. Hitchcock's Arrangement.—Stratified and Unstratified.—Distribution of Primary Rocks.—In New-England.—In the Middle States.—Syenitic Porphyry.—Primary Stratified Rocks.—Gneiss.—Mica Slate.—Talcose Slate.—Granular Limestone.—Minerals in Granitoid Rocks.

In treating of the geology of the United States, we shall follow the same arrangement which we have adopted in the forepart of our treatise, and describe the different formations in the following order. 1. *Primary Rocks;* 2. *Transition Rocks;* 3. *Secondary;* 4. *Tertiary;* 5. *Basaltic and Volcanic;* 6. *Alluvial and Diluvial.* Some geologists begin at the surface and go down; we prefer to commence at the bottom, with what have usually been called the primary rocks, and work our way upward.

Professor Hitchcock* has arranged the primitive rocks of Massachusetts chiefly under three groups, as follows: the *first group* embraces *granite, syenite, greenstone, and porphyry:* the *second, gneiss, hornblende slate, and quartz rock:* the *third, mica slate, talcose slate, chlorite slate,* and *hornblende slate.* A *fourth* group embraces *limestone, scapolite rock, steatite,* and *serpentine,* which may be called miscellaneous rocks. The student of geology will find it advantageous to furnish himself with specimens of all these rocks; but, when he goes abroad to observe, he will find that *granite, gneiss,* and *mica*

* Report on the Geology of Massachusetts.

slate constitute the chief rocks in the primitive formations. Doubtless the most simple classification of primitive rocks is into *unstratified* and *stratified ;* including under the former *granite*, *syenite*, *porphyry*, and *greenstone*, and perhaps *granular limestone*, all of which probably owe their origin to igneous causes ; while the latter would embrace *gneiss*, *mica slate*, *argillaceous*, *talcose*, and *chlorite slate*, *quartz rock*, &c., which have been produced by the consolidation of the particles resulting from the disintegration of the igneous rocks, and in some instances of that of the quartz rock, modified by subsequent heat. At any rate, few geologists of the present day, or perhaps none who deserve the name, can be found who will deny a belief in the igneous origin of the unstratified rocks, and who do not regard them as merely varieties of the same melted mixture, whose peculiarities resulted from the modes in which they were cooled and crystallized, and included among the stratified rocks. It by no means follows, from this view of the subject, that all the unstratitified rocks are of the same age, as they were doubtless protruded at different periods. Granite veins have, for example, been found overlying chalk ; basalt has cut through rocks of every formation ; and lava every day overspreads diluvium and alluvium.

Professor Hitchcock speaks of a pseudo-stratification of granite in Worcester ; but this is doubtless to be attributed to the process of cooling, under peculiar circumstances of position, as we see in basalt ; it sometimes assuming a columnar form, at other times not. Throughout New-England granite usually occurs in the form of veins and protruding masses, sometimes lying between the strata of other rocks, but rarely, if ever, overlying them. Professor Hitchcock gives numerous instances of such veins in *mica slate*, *hornblende slate*, *gneiss*, *micaceous limestone*, &c. Such veins abound in the gneiss rock of Manhattan Island. These veins penetrate only the oldest rocks, the clay slate being the latest in which they are found. The intrusion of these veins seems to have produced very little disturbance in the rocks containing them.

We meet with the primary rocks as far to the north on this continent as human discovery has yet extended. The Werner Mountains, on the coast of Greenland, which, according to Scoresby, rise to an elevation of 6000 feet, are composed of primitive rock, granite, gneiss, mica slate, hornblende slate, &c. Primitive rocks also abound on the west coast of Greenland, in connexion, however, with secondary, tertiary, and alluvial. On the west side of Baffin's Bay, as far as the seventy-fourth degree of north latitude, Captain Parry found the predominating rock to be primitive, and of the same varieties as the preceding. As we come to the south we find the hills bordering on Hudson's Bay, which have an average elevation of about 800 feet, and the highest summits not exceeding 1500 feet, to consist chiefly of primitive rocks similar to those already mentioned, and abounding in interesting minerals, such as *zircon*, *beryl*, *garnet*, *actynolite*, *tremolite*, *rock crystal*, *asbestos*, *rhomb spar*, *iron ore*, *coccolite*, *graphite*, &c. Tracing the country still farther south, along the coast of Labrador and Newfoundland, we still find the primary formations constituting the mountain ranges of Canada, New-Brunswick, and Nova Scotia, and bounding the coast through the whole extent of New-England. Indeed, the primary formations occupy nearly the whole area of the New-England States. From their extreme eastern boundary they range westward, following the St. Lawrence to the lower extremity of Lake Ontario. From that point or at the Thousand Isles, the edge of these formations may be traced in a southeast course to the southern point of Lake George. Farther south than this the western boundary passes near Bennington, Vermont, and along the western line of Massachusetts, and, crossing the Hudson between Peekskill and Newburgh, under the name of the *Highlands*, it stretches away through a part of New-Jersey, forming a wide zone of many nearly parallel ridges, with steep sides and very undulating outline, or low mountain ranges of moderate elevation, rarely exceeding 600 feet, to its termination in the northern part of Lancaster county, Pennsylvania. Upon the New-York State line, where this belt of hills is widest, they are limited for several miles on the southeast by the Valley of the Ramapo, and on the northwest by that of the Walkill. The breadth of this zone of hills diminishes, therefore, pretty regularly and rapidly in its extension towards the Delaware, occupying about twenty-three miles upon the New-York line, and scarcely eight upon that near the Delaware. The prevailing direction of the strata, which are nearly all primary, thoughout the region is northeast by north, and southwest by south, while most of the principal valleys are composed of blue limestone.* Near Trenton we again meet with gneiss rock, which, in connexion with mica slate, granite, &c., we trace far to the southwest. We have this western border of the primary formation across the Susquehanna, near Columbia, and through Maryland and Virginia, keeping parallel with the eastern ranges of the Blue Ridge System. The southeast edge of the New-England primary is along the north shore of Long Island Sound, taking in a small portion of the west end of Long Island, and passing through the city of New-York and Staten Island to Perth Amboy. Here these formations are interrupted by an overlapping of the red shale series in New-Jersey, and do not reappear until we find them in a mere point, six miles to the northeast of

* Professor Rogers's Report on the Geological Survey of the State of New Jersey, 1836.

Trenton. From that point they extend south, forming the eastern boundary of the primary area above mentioned. The eastern line of this is marked by the western limit of the tertiary and cretaceous rocks of the Atlantic plain; its western or northwestern boundary is traced crossing the Delaware a mile and a half above Trenton, and meeting the Schuylkill about twelve miles from Philadelphia. As the belt widens still to the northwest, the same line passes more and more off from the coast, passing the Potomac river twenty-two miles west of Washington, and merging into the previously traced belt somewhere near the Rappahannock, in Virginia. The separation of the primary into these two tracts over so wide a space is owing to the position of the very long belt of the red shale and sandstone series, which, from the Rappahannock to the Hudson, ranges in a central direction between them. An insolated group of the same rocks lie along the Valley of the Connecticut, in a detatched basin in the eastern section of Massachusetts, between Boston and Rhode Island, and also along the country bordering the Hudson River, and Lakes George and Champlain.

The primary rocks, then, range in a continuous belt through Virginia, North Carolina, South Carolina, and Georgia, as far as the Alabama river in Alabama, and occupy a breadth in most parts of this course of from 80 to 100 miles, having for their eastern boundary the horizontal strata of the Atlantic plains, and for their western the great Appalachian valley lying at the base of the Blue Ridge, and the long range of mountains which stretch farther to the southwest. Thus, from the coast of New-Brunswick to the mouth of the Hudson, except the Peninsula of Cape Cod, the sea washes against primary rocks, sometimes low, sometimes in bold projecting cliffs. From this ocean boundary all the region embracing the New-England States, and the northern section of New-York as far to the northwest as the St. Lawrence river, consists of primary rocks, with the exceptions we have already pointed out, and shall more particularly describe under *Secondary Rocks*.

Primary rocks also compose a principal part of the materials of the range called the Ozark Mountains, west of the Mississippi; and far off on the western side of the continent, in the vast chain of the Rocky Mountains, they exist in promiscuous profusion, constituting far grander phenomena than belong to any part of the range skirting the Atlantic. Extending far to the northwest, we then trace the primitive range, in the shape of low hills, with rounded summits, and more or less precipitous sides, across the continent to the shores of Lake Superior, forming a belt of about 200 miles in width.

Unstratified Rocks.—The greater portion of the primary rocks of the Eastern States belong to the stratified class, such as *gneiss*, *mica slate*, &c., and those of the Middle and Southern States consist of this class exclusively. The unstratified rocks of the United States occur chiefly in the country east of the Hudson River, and, as we have already stated, may be included under four varieties, viz., *granite*, *syenite*, *porphyry*, and *greenstone*. These are distributed in numerous isolated patches among the stratified rocks throughout the whole of the New-England States, but particularly in the eastern part of Massachusetts and in the vicinity of Boston, where they occupy more than half the surface. They also stretch up along each side of the Connecticut River, at a distance of from 5 to 20 miles, enclosing the new red sandstone, and giving peculiar features to this beautiful portion of country.

The *granite* of New-England is thus distributed in such irregular patches and so many isolated ranges, that it is impossible, within the compass of a work like this, to give anything like a correct delineation of its boundaries. We shall, therefore, only present a few brief notices of its occurrence. A belt of granite traverses nearly the whole breadth of Massachusetts. Commencing near Andover, it runs between a region of *syenite* on the east, into which it sometimes graduates, and a belt of *gneiss* and *mica slate* on its west, as far south as Rhode Island. Portions of this mass, especially in Rhode Island, are fine-grained, and well adapted for architectural purposes, for which it is extensively wrought in the vicinity of Providence. Another broad mass of this rock extends from the coast of Narragansett and Buzzard's Bays, in a northeast direction, towards the opposite side of the Peninsula of Massachusetts. This, though usually coarse-grained, is in some places, as at Fall River, of a fine grain, and suitable for building. As we go farther west we meet with detached masses of granite protruding through the gneiss and mica slate; and a similar arrangement prevails in the districts of New-England to the north of this state. For example, wide expanses of granite rocks show themselves near the coast, and as we proceed westward they become merely isolated masses, as it were, thrust through the gneiss, mica slate, and other stratified rocks. Granite of very superior beauty, associated with syenite, extends in a convenient belt around Boston, at a distance of 10 or 20 miles, upon the north, west, and south. From Cohasset to Quincy, and also between Cape Ann and Salem, it is very extensively quarried, the rock from the large quarries being now widely known in many of the cities of the United States. At the quarry at Fall River, blocks of beautiful granite, from 50 to 60 feet long, are sometimes procured. At the quarries in Quincy have lately been obtained eighteen pillars for the New-York Exchange, being the largest ever procured in this country, weighing each 33 tons. They are fluted, and finished in the most perfect manner, with carved capitals, and cost 4000 dollars each.

That variety of granite that contains hornblende in the place of the mica, and known under the name of *syenite*,* is found in abundance in the same neighbourhood with the granites here mentioned, and is itself almost as largely wrought as the true granite, or triple combination of *quartz*, *feldspar*, and *mica*. The Astor House in the city of New-York is built of this stone; and from the same quarry are obtained a large portion of the doorposts, window-sills, capstones, and foundation pillars of the buildings now being erected in that city. The Washington Bank in Boston, and the Bunker Hill Monument, are built also of syenite.

Porphyry, *syenitic porphyry*, and *porphyritic greenstone*, abound in various places adjacent to the coast of New-England, especially to the north and south of Boston. Near Lynn the porphyry assumes all the dark purple and other tints, with the fine polish of the best antique varieties; and when ornamental architecture shall be more cultivated in this country, this rock will doubtless be considered as of inestimable value.

Syenitic porphyry, or a syenite with imbedded crystals of feldspar, occurs plentifully in fine specimens near Cape Ann; and a rock splendidly ornamented, consisting of a fine greenstone paste, with disseminated crystals of greenish feldspar, and sometimes called porphyritic greenstone, is found in large veins traversing syenite not far from the same headland.

* From *Sienna*, in Upper Egypt, whence were obtained the well-known Egyptian monuments, such as Cleopatra's Needle, Pompey's Pillar, Trajan's Pillar in Rome, &c. Many writers describe the syenite as consisting of feldspar and hornblende. The rock from Sienna is now ascertained to be a *red granite*, containing black mica and a small portion of hornblende

Primary Stratified Rocks.

After presenting this general outline of the range of the primitive formations in the United States, and the unstratified rocks in particular, it will be proper to devote a few remarks to the consideration of the primary stratified rocks.

*Gneiss.**—The oldest of these, and one that occupies more surface in New-England than any other, is gneiss rock. Indeed, it is one of the most extensive formations in all primitive countries. With the same mineralogical constitution as granite, and lying next to it, with its ingredients arranged in a stratified form, it has evidently been produced by the disintegration of that rock, and its structure modified by various causes. There are many varieties of this rock, according to its structure and composition, as *granitic*, *lamellar*, *porphyritic*, *talcose*, &c. Many of the mountain ranges and hills of the New-England States are composed of gneiss; such as the White Mountains of New-Hampshire, some of the Green Mountain ranges of Vermont, Hoosic and Wachusett Mountains in Massachusetts, and we trace it forming most of the hills and ridges in the northern and western part of Connecticut.

A large portion of the mountainous districts in the State of New-York are formed of gneiss; as those of Essex, Montgomery, Herkimer, Oneida, St. Lawrence, Orange, Dutchess, Putnam, and Westchester counties. It forms the lofty Highlands near West Point, as well as the high peaks of Essex, one of which (Mount Marcy) rises 5467 feet above the ocean. In many parts of this state, the stratification of this rock is very obscure, and its texture confusedly crystalline, the mica not being distinctly disposed in parallel layers. Indeed, it may often be seen passing into distinct granite

* See page 63 for a description of gneiss.

thus baffling all attempts at classification. The gneiss region in some parts of New-England, as in Worcester county (Massachusetts), furnishes an excellent soil, owing to the sulphuret of iron contained in the rock, which causes its rapid disintegration. In this state, as a general rule, gneiss contains but little iron, and is, consequently, very tough and indestructible; the soil, accordingly, where it predominates, is thin and poor. Mr. Emmons remarks, "That in Montgomery, Herkimer, and Oneida counties, where the primary mass predominates, we find one general character impressed on its surface, that of having few inhabitants; and so well fixed are its limits, that it may in truth be said, that population and that class of rocks are negatively characteristic of each other. The connexion exhibited in these counties of rock and soil, furnishes another to the very many instances of the importance of geology to the causes of the difference in the different parts of the earth as to agriculture and its consequent population."

Much of the primitive range already described as extending south through the Atlantic States is composed of gneiss. This rock forms a fine building stone, and it is very extensively quarried for that purpose in the Easern States, under the name of granite.

Mica Slate.—This rock ranks next to gneiss in its situation and age, and, indeed, is generally associated with it. Its essential ingredients are quartz and mica, but the mica predominates. Single specimens may contain more quartz, but we must look to the whole mass of the rock. There are many varieties of mica slate as well as of gneiss, Professor Hitchcock having enumerated as many as 14; but they are, in general, too unimportant to need description. Next to gneiss, it occupies more space than any of the other rocks of New-England. A great portion of Massachusetts is mica slate, and a broad belt of it runs north and south nearly through the centre of the state, striking north into New-Hampshire and Maine. It forms Saddle Mountain in Williamstown, near 4000 feet high, and the highest point in the state. The Taconic range, extending through Berkshire county, and south through Connecticut and Dutchess county, is composed of mica slate, and so also is a great portion of the Hoosack Mountain range, which includes all the elevated land between the valleys of Berkshire and the Connecticut. It often approximates to argillaceous and talcose slate in Berkshire county, and is sometimes mistaken for them. The mica slate formations in New-England generally run north and south, and the strata, for the most part, dip to the east, with an angle of from 20 to 90 degrees. This rock is extensively used for flagging the sidewaks of cities, as it is easily split into layers.

Talcose Slate.—This is another of the primary rocks, and under it may be included chlorite slate and stealite, or soapstone, as these are only varieties of the same species. It is composed of *talc* and quartz, though it sometimes contains other ingredients, as feldspar and hornblende. We find it connected with mica slate in New-England, as in the Hoosack and Green Mountain range, and very perfect specimens of it may be observed in Hawley and Plainfield. It also abounds in the Middle and Southern States. Steaite or soapstone abounds in the vicinity of the Rocky Mountains, where it is procured by the Indians for the bowls of tobacco-pipes; also near the Falls of St. Anthony; in Maryland, near Baltimore; in Pennsylvania, near Philadelphia; and Staten Island, where it forms a large proportion of the elevated grounds on the eastern part of the island. It is extensively employed for aqueducts, coal furnaces, &c.

Granular Limestone.—There is no rock more extensively diffused than this, and none more readily detected, as a single drop of acid will cause an effervescence. Its structure and appearance are too well known to need description. It forms an extensive bed through the whole extent of Berkshire county, and thence it stretches through Vermont far north into Canada. The same range also extends south through the State of Connecticut, where in many places it is burned for lime. It also abounds in New-Hampshire and Maine, and, indeed, in all the states where the other primitive rocks are found. Professor Hitchcock regards the Berkshire deposite as one of the most extensive ranges of primary limestone in the world. It is of a pure white colour and of a highly crystalline texture, as may be seen by examining the City Hall in the city of New-York, which is built of this stone; or the Girard College, Philadelphia. Blocks are obtained from a ledge in Sheffield more than 50 feet long and eight feet thick. We shall hereafter speak of the economical uses of this valuable rock.

The non-stratified or granitoid rocks, as they have been called, contain, among others, the following minerals, viz., iron, tin, zinc, plumbago (black lead), titanium, molybdena, lead, copper, gold, beryl, garnet, topaz, tourmaline, zircon, chrysoberyl, pyroxene, hyperstene, spinelle, epidote, pinite, idocrase, diallage, &c. The same minerals are also found in the stratified rocks; and, in addition, anthracite coal has been met with, though not in large quantities, as at Worcester, Massachusetts, in mica slate.*

* It is claimed by some geologists that this is a transition formation.

CHAPTER XXI.

GEOLOGY OF THE UNITED STATES.

TRANSITION ROCKS.

Definition.—Clay Slate.—Its Distribution.—Transition Limestone.—Mr. M'Clure's Description of this Formation.—Mr. Featherstonhaugh's Old Red Sandstone.—Its Geological Distribution.

We have already remarked that the transition rocks are those that rest on the primary, and, as they seem to *pass into* them, they are called *transition*, from the Latin words *trans* and *eo*, to go or pass over. They are sometimes called intermediate; but as it is difficult to tell where they begin or where they end, some geologists, as Professor Sedgwick, Mr. Brown, &c., merge them either wholly in the primary, or partly in that and partly in the secondary classes. As the earliest of the transition class, argillaceous slate, does contain fossil* organic remains, we find it necessary, from our definition of primary rocks, and far more suited to the existing order of nature, to place this rock, which has generally been arranged among the latter, among the transition series. But, without entering on the unprofitable dispute whether clay slate should belong to the transition, or whether, indeed, there should be any transition class or not, our object will be at-

* "This is the oldest system of strata in which organic remains are certainly known to occur; and it may surprise the speculators in cosmogony to hear that these, the most ancient forms of life known to us, should be not plants, but animals" &c.—Philips's Geology, vol. i., p. 128.

tained if we succeed in pointing out the relative situation of those rocks usually assigned to this class, and their topography in this country.

These rocks are, 1. *Clay Slate;* 2. *Transition or Mountain Limestone;* 3. *Graywacke and Graywacke Slate*, passing into *Old Red Sandstone.*

Argillaceous or *Clay Slate.*—We have already remarked that this rock is composed of clay, more or less indurated, and readily splits into distinct laminæ; from which circumstance it is called roof-slate. Some geologists make this rock include the graywacke formation; others exclude the latter. This rock abounds in the vicinity of mica slate, into which it seems to pass by insensible gradations. Argillaceous slate forms three ranges in Massachusetts, viz., in the counties of Worcester, Franklin, and Berkshire; extending up the Connecticut Valley far into New-Hampshire and Maine, and through the whole extent of the western boundary of the state far into Vermont, and probably to Canada. It forms a great part of Columbia and Rensselaer counties, and is wrought for roofing purposes in Hoosack, Lebanon, and Hillsdale. It is connected on the east with mica slate; on the west with graywacke, passing into both. Near the Susquehanna, in Pennsylvania, it is extensively quarried for roofs, and over 1600 tons annually procured, which sells in Baltimore at 22 dollars a ton. A ton of slate forms about 200 superficial feet when on the roof. It is unnecessary to specify the topographical distribution of this rock; suffice it to say that it accompanies the primary rocks throughout the United States, extending from Canada, in patches, or a continuous formation, to Alabama. The strata of this rock, for the most part, dip to the east with an angle of from 15 to 90 degrees. *Shale* is only a variety of argillaceous slate, containing a greater proportion of carbon, but it is often a later formation.

These rocks belong to the graywacke and lower fossiliferous groups of De la Beche, and the latter might, with as much propriety, be referred to the lower secondary formations as placed in the present group.

Transition Limestone.—We have already given a short description of this rock (page 82). It is less crystalline than the primary, and more so than the secondary, being of an intermediate character between both. It is generally of a dark gray colour, and sometimes black. This colour is owing to carbon and bitumen disseminated through it. It often passes into magnesian limestone, and frequently contains alumina. It is not rich in metals, though copper is found in it in Virginia. It contains numerous fossil organic remains, such as of fish, and testaceous animals. Of these, the *orthocera*, the *encrinite*, the *productus*, the *terebratula*, and the *trilobite*, are the most common. The latter is often met with in the transition limestone at Trenton Falls in this state. The same formation also contains numerous coralliform crystallizations. "The transition limestone," says Professor Renwick, "occupies a narrow belt of very great length in the United States. In North Carolina, Virginia, Maryland, Pennsylvania, and New-Jersey, it lies in a valley, often diversified by hills of moderate elevation, between the first and second ridges of the Appalachian group. It enters the State of New-York in Orange county, and follows for a time the course of the Walkill. Thence it passes towards the Hudson River at Newburgh, where it is covered by diluvial gravel, but reappears at the surface on the eastern bank at Fishkill. From thence to Rhinebeck it is wholly confined to the eastern side of the Hudson; here it again crosses the river, and spreads to a considerable width in the neighbourhood of Kingston and Catskill. At Hudson it occupies both banks of the river, and extends eastward for several miles, but here finally crosses the river. North of

Kingston it changes its level, and begins to rise to a mountain height, forming the Indian ridge, which, although small when compared with the neighbouring Catskills, equals the Highlands in elevation. This ridge is produced into the Heldeberg, which passes to the northwest through Albany and Schoharie counties. In the latter it paves a rich valley, and, rising again, encloses the valley of the Mohawk on both sides, and often with precipitous cliffs. At the Little Falls of the Mohawk it is covered by the formation of red sandstone and graywacke; but it is speedily seen again, forming the valley of West Canada Creek, and there rises into a table-land, whose southern slope presents the aspect of a mountain ridge. In issuing from this ridge, Canada Creek forms Trenton Falls, and the formation is opened to a great depth. To the north of Trenton the formation extends to a great breadth, and may be traced to the northwest across the St. Lawrence and into Canada."

Mr. M'Clure, who is probably better acquainted with the geology of the United States, from personal observation, than any other individual, limits the field of transition rocks by the northwest boundary of the primitive formation, which we have already described as extending from Lake Champlain to near the river Alabama. Of course it touches, on the northwest side, the southwest edge of the great secondary formation, in a line that passes considerably to the westward of the ridge which divides the eastern and western waters in Georgia, North Carolina, and part of Virginia, and runs near it in the northern part of that state, and in the states of Pennsylvania and New-Jersey. This line of demarcation runs between the Alabama and Tombigbee rivers, to the west of the north fork of the Holstein, till it joins the Alleghany Mountains, near the White Sulphur Springs, in Green Brier county, and along that dividing ridge to Bedford county, in Pennsylvania; and from thence northeast through the State of New-York to Fort Ann, near Lake Champlain, and follows the east side of that lake to Canada. The separation of the transition and secondary is not so regularly and distinctly traced as that of the transition and primitive; many large valleys are formed of horizontal secondary limestone, full of shells, while the ridges on each side consist of transition rocks. The two formations doubtless interlock, and are mixed in many places; but north west of the line above described it is probable little or no transition will be found, while to the southeast partial formations do occur. The transition formation is generally broadest where the primitive is narrowest, and vice versa, and is from 20 to 100 miles in width; the stratification runs from a north and south to a northeast and southwest direction, dipping generally to the northwest, at an angle in most places under 45 degrees from the horizon. On the edge of the primitive, it deviates in some places from this general rule, and dips for a short distance to the southeast. The most elevated ground is on the confines of North Carolina and Georgia, where it descends towards the northwest until it meets the secondary. The outline of the mountains of the transition formation is almost a straight line, with few interruptions, bounding long parallel ridges of nearly the same height, declining gently towards the side, where the stratification dips from the horizon, and more precipitous on the opposite side, where the edge of the strata come out upon the surface.

The inclined strata are, indeed, so characteristic of this formation, that Mr. Featherstonhaugh remarks, "Wherever the geological student finds the strata thrown out of the horizontal line and dipping in any direction, he may, with few exceptions, enumerate such hills among the transition rocks, the old red sandstone inclusive. Few of the rocks of the United States lying above them are found with the planes of this strata making any sensible angle with the horizon," &c. (Geol. Report, 1836.) This, then, will be one very important distinction between the transition and secondary rocks. We have already enumerated the rocks of which this formation is composed, viz., *slate*, *graywacke* and *graywacke slate*, and *limestone;* the latter we find of all colours, from a white to a dark blue or black, often intermixed with graywacke slate, and containing crystals of calcareous spar and gypsum. M'Clure describes it as occurring in beds of from 50 to 5000 feet in width, alternating with the rocks above mentioned. Near the borders of the primitive there occurs a sort of silicious aggregate, having particles of a light blue colour, from the size of a pin's head to an egg, held together by a cement of slate or quartz. The limestone, graywacke, and graywacke slate generally occupy the valleys, and this quartzy aggregate the ridges. "Among which," says M'Clure, "is what is called the country buhrstone or millstone grit, which must not be confounded with another rock likewise called millstone grit, which is a small-grained granite, with much quartz, found in the primitive formation."

The *old red sandstone*, which we have placed as the last and uppermost of the transition series, covers a considerable extent of country in the United States, and is evidently of mechanical origin, being composed chiefly of quartz mingled with mica and feldspar. Sometimes it is a conglomerate, made up of fragments of the primitive and the other transition rocks. It was probably this rock that M'Clure called millstone grit. We have already stated that it alternates with the transition limestone, and that its layers are often divided by beds of clay either soft or indurated.

Prof. Renwick, speaking of the old red sandstone group, under which he includes graywacke, remarks, that he "first observed it in the State of

New-York, in a narrow ridge, through which the Mohawk makes its way at the Little Falls. A few miles south of this it meets the western bend of the Catskill's, and spreads out to a breadth of 200 miles between the Pine Orchard and Lake Canandaigua. The southeastern limit is the Shawangunk Mountains and the Blue Ridge of Pennsylvania, parallel with which it extends to Georgia and Tennessee in a broad belt, forming the loftiest summits of the Alleghany. Of all these ridges it constitutes the eastern face, and dips with more or less rapidity to the northwest, being in some places almost vertical."

Prof. Renwick says, that "the anthracite coal formation of Pennsylvania rests immediately on the red sandstone." Prof. Hitchcock observes, that he "suspects the Pennsylvania anthracite occurs in the higher beds of the graywacke, perhaps even in the millstone grit, and the Rhode Island anthracite in the lower beds of the graywacke." M'Clure simply states, that both the Rhode Island and Pennsylvania anthracite occur in the transition formation, while, again, Prof. Renwick remarks, that "those who consider the anthracite of Pennsylvania to belong to the transition order, err." We shall hereafter consider this subject more in detail. Prof. Henry D. Rogers, of Pennsylvania, remarks, in relation to the sandstone under consideration, that "it is not confined to the Appalachian region of Pennsylvania, but that it possesses a prodigiously extensive range, not only through Maryland and Virginia, but in a contrary direction through New-Jersey and New-York, and, I believe, beyond those limits, constituting everywhere the lowermost formation of the widespread secondary strata, which it encircles in a somewhat interrupted belt, following the primary boundary of these rocks from Tennessee to Lake Champlain, and thence northwestward to the northern shore of Lake Huron and Lake Superior."

The Catskill Mountains, from the base to near the loftiest summits, are composed of strata of this sandstone, through a thickness of 3000 feet or more

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CHAPTER XXII.

GEOLOGY OF THE UNITED STATES.

LOWER SECONDARY FORMATIONS.

Carboniferous Group (De la Beche). *Medial Order.*

Secondary Rocks—Their Division.—Carboniferous Limestone—Its Range.—Mr. Featherstonhaugh's Account of it.—The Coal Measures—Of what they Consist—Their Situation.—Anthracite Coal Measures—Prof. Rogers's Account of them.—The Shales.—Section of Coal Measures of Pennsylvania.—Section of Carboniferous System of Ohio.—Coal Measures on Kenawha River—At Wheeling, Va.—At Pittsburgh—At Kiskiminitas.—Millstone Grit and Shale.—May we expect to find Coal in New-York?

Having "worked our passage" through the contorted strata of the transition series, we are now prepared to launch out upon the great secondary formation, where, if we mistake not, we shall find smoother sailing.

The lower secondary rocks consist of three series:

1. *Carboniferous Limestone.*
2. *The Coal Measures.*
3. *Millstone Grit and Shale.*

Carboniferous Limestone.—Bearing in mind, then, that we are working our way upward, from granite, the lowermost rock, to the surface, we next come to the carboniferous limestone, resting upon the old red sandstone* just described.

* At Lewiston, ten miles below the Falls of Niagara, we can see the old red sandstone immediately under the great carboniferous limestone formation.

This limestone is usually compact, occasionally granular, and containing crystals of carbonate and sulphate of lime, as at Niagara Falls. It sometimes passes into magnesian and argillaceous carbonates of lime. Its colour, like that of the transition, passes through all shades from white to black, being coloured and variegated by metallic oxides, thus yielding many of the most valuable marbles. When it contains alumine, as it often does, it forms an excellent hydraulic cement. It contains numerous fossil organic remains; the petrifactions consisting of white carbonate of lime, thus causing a most beautiful appearance when the mass is polished. This limestone is very rich in minerals, such as lead, iron, copper, zinc, antimony, bitumen, and crystals of various earthy minerals. It is this rock which chiefly forms that vast formation which extends over the whole of the United States west of the Alleghany Mountains, and north to Lake Champlain, forming the bed of Lake Erie and the precipice of Niagara, as already described.

Mr. Featherstonhaugh states that he "has traced the eastern border of the carboniferous limestone, conforming to the course of the other mineral formations east of the Mississippi, more than 1000 miles, running to the west of south from the State of New-York, to the 35th degree of north latitude in the State of Alabama; the course is then changed, and lies to the north of west, leaving Little Rock, on the Arkansas, about 30 miles to the south, and disappearing between 500 and 600 miles from the Rocky Mountains. This deposite extends uninterruptedly a geographical distance of at least 1500 miles from east to west, underlying portions of the States of New-York, Pennsylvania, Ohio, Indiana, Illinois, Missouri, and the Territory of Arkansas on that line. In Tennessee, Kentucky, Virginia, and Maryland, it is bounded by a line of which the Cumberland Mountains form a part. In the plains through which the

Mississippi flows, and which include the Illinois prairies, it appears like a continuous floor, forming an almost continuous flat; for although the superficial level is irregular, that of the calcareous formation, lying beneath the arable soil, seldom seems to change its elevation materially."

Immediately resting upon it, though sometimes alternating with it, we find

The Coal Measures.

The *Coal Measures*, so called, consist of several regular strata, the most important of which are various kinds of *sandstones*, differing considerably in structure and in appearance; *shale*, or bituminous slate; *slaty clay; coal*, *bituminous* and *anthracite; ironstone;* to which may be added, the *millstone grit* above, and the *carboniferous limestone* beneath, which alternate occasionally with the coal measures. As the coal measures thus sometimes overlie the millstone grit and shale, and sometimes alternate with the carboniferous limestone, it is evident they may occupy any place, or, in geological language, be of any date between the new and old red sandstone. Coal has never been found in either of these last formations in quantities sufficient to pay the expense of working.

Anthracite Coal Measures.

These comprise a very miscellaneous group of materials, consisting of beds of coal, and extensive series of shales, sandstones, and conglomerates, in frequently repeated alternations.

Professor Rogers, state geologist of Pennsylvania, gives the following account of them in that state: "Among the coal-seams at the base of the series we often find a conglomerate of the very coarsest sort, identical in all particulars with the rock which characterizes the upper portion of the next underlying formation. This rock marks the gradation from the one set of deposites to the other, and points to the curious fact that the processes which brought together the materials of the coal commenced before the previous movements that caused the conglomerate had wholly ceased. This very coarse aggregate has rarely more than one or two coal-beds below it; and, ascending a little in the series, we find that its place is supplied by thick beds of shale and masses of soft argillaceous sandstones, some of whose layers have a sprinkling of pebbles, which give the aspect of conglomerates. These pebbles are smaller and more irregular than those composing the rock at the very base of the series. The coal, and the slates immediately in contact with the coal, lie interstratified with these numerous coarse beds in an alternating group of great thickness.

" Between the conglomerates, or even the coarser sandstones and the beds of coal, argillaceous sandstones and blue shales are almost invariably interposed. The predominant rock of the upper part of the series is a compact blue sandstone, containing much argillaceous matter and oxide of iron, which cause the atmospheric agents to decompose it superficially, and to impart a dingy brown colour and a tendency to a conchoidal fracture, and to a scaling off at the corners.

" The shales, which are next in importance to the argillaceous sandstones, are commonly of a dark blue or bluish gray colour when freshly broken; but many of them, by exposure to the atmosphere and to the vicissitudes of the seasons, assume a brownish ochreous hue, and crumble rapidly to pieces. Occasionally these shales contain highly ferruginous bands, in some of which occur layers of tolerably rich argillaceous iron ore. In the anthracite coal measures, as a general rule, this ore does not appear to exist in that abundance which it exhibits in many portions of the bituminous coal series northwest of the Alleghany Mountains. These bluish shales contain, though not abundantly, very beautiful impressions of ferns and stems of calamites, and in the lower portions of the deposite the stems and leaves of other curious vegetable fossils, as lepidodendron, sigillaria, and cactus.

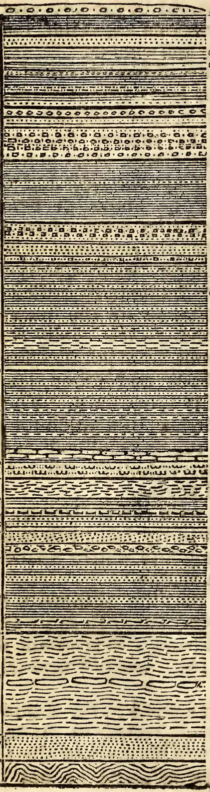
"In the immediate vicinity of the seams of coal, these shales become more or less carbonaceous, and acquire a darker colour and a more purely argillaceous texture. On such the miners bestow the name of *coal slates.* These slates, it is generally thought, differ materially in appearance and composition, according as they lie above or beneath the coal-seams. The overlying slate often contains innumerable extremely thin sheets of pure anthracite, minutely interlaminated with equally delicate layers of slate. This is technically called *bone coal*, and is frequently mistaken by the inexperienced for pure anthracite, though it is easily recognised by its tendency to split into parallel layers, or by the number of the ferns and other delicate vegetable impressions usually found in it. The underlying slate is, on the contrary, of a much tougher consistence, and of a more regular and well-defined fracture, breaking into firm splintery masses instead of loosely aggregated scales.

"These slates, in contact with the coal-beds, vary from one to twenty or even thirty feet in thickness, and not unfrequently occupy the entire space between two contiguous coal-seams."

We have already stated that the anthracite beds of Worcester (Massachusetts) occur in mica slate; those in Mansfield, Middleborough, Wrentham, &c., occur in graywacke, as well as those of Cumberland in Rhode Island.

The coal measures, as exhibited in the following sections, it will be understood, belong to the lower secondary rocks; that is, they lie next to the transition rocks, and, according to some of our best

Table showing the Order, Character, and Maximum Thicknesses of the Lower Secondary Formations of Pennsylvania, east of the Susquehanna.



No.	Feet	
XIII	6250	Coal Measures, consisting of seams of Coal, dark shales, argillaceous Sandstones, and Silicious Conglomerates. (Vegetable Fossils.)
XII	1400	Silicious Conglomerate.
XI	3000	Red Shale. Thin calcareous Conglomerate
X	2000	Sandstone and Conglomerate.
IX	6000	Red Shales, and Red, Gray, and Buff-coloured Argillaceous Sandstones. A few marine fossils.
VIII	5000	Olive-coloured Slate and Gray Argillaceous Sandstone. Many Marine Fossils. Limestone.
VII	700	Coarse white Sandstone. (Cavities of fossils.)
VI	900	Blue Argillaceous Limestone (fossils).
V	2000	Red and Variegated (fossiliferous iron ore). Shales and Sandstone (fucoides).
IV	1800	White Sandstone (fucoides).
III	6000	(Roofing Slates.) Dark Slate and Argillaceous Sandstone. (A few fossils.) Bed of Limestone.
II	6000!	Blue Limestone. Beds of chert. (A few fossils.)
I	1000!	Compact White Sandstone.
		Gneiss, &c.

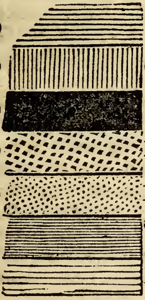
geologists, as already stated, are contained in formations of the period of the graywacke group. They extend, according to Professor Rogers, more than 42,000 feet in depth. It will be recollected that we described three distinct mountain ranges, extending through the Middle and Southern States, as, 1. The *Blue Ridge System* on the east; 2. The *Alleghany* on the west; and between these, 3. The *Appalachian*, consisting of a wide belt of parallel mountain ridges, with deep intervening valleys. Now it is the rocks of this region that constitute the oldest fossiliferous group of the United States, and that contain the anthracite coal; and because they are next in the descending order to those containing the bituminous coal, they are regarded as equivalent to the class of strata in Europe known as the graywacke group. But whether they are or not is of no great consequence. The anthracite coal-fields embraced in these strata, so far as yet discovered, lie chiefly to the northeast of the Susquehanna River. If we trace a parallelogram, one line following the Kittatinny or Blue Mountains from the Water Gap of the river Lehigh to the Susquehanna, another from that mountain up that last river to its north branch, and a third along the north branch and its tributary, the Lackawanna, till we reach a point almost due north from the point we started from, we shall then enclose nearly all the genuine anthracite seams hitherto discovered in Pennsylvania. Then, to form a correct idea of the situation of the coal, we have only to imagine that a set of strata, *conglomerates*, *grits*, *shales*, and thick beds of *anthracite*, were deposited on some wide and nearly horizontal plain, and not collected, as appears to have occurred with many coal-fields, into troughs or basins previously formed. Then conceive the whole of this level once to have been converted into an undulating surface of valley, hill, and mountain, by some general disturbing cause. We then have the coal as it actually exists, both upon the hills and in the valleys, forming at times a portion of the strata of the mountains, and only occasionally lying in a basin form between the ridges. Lying nearer the transition and primitive rocks, which are now universally allowed to have been once either in a melted state by fire, or subjected to great heat when the superincumbent strata were upraised, forming hills and mountains, we thus account for the fact that the coal of these strata contain no bitumen, it having been dissipated by the heat, while the bituminous coal measure lying higher up in the series escaped its effects. To the same purpose Dr. Hildreth remarks, that "there seems to have been three different deposites of coal throughout the main coal-region of the west. After the vegetable materials which form the coal-bed were deposited or buried under the superincumbent strata, it would seem that a strong degree of heat had been applied, in addition to the pressure, before they could assume their present bituminized appearance. As we approach the coal-beds in the transition and primitive rocks, the evidences of heat are still more apparent, removing from the anthracite beds all, or nearly all, their bituminous contents, and in the primitive changing anthracite into graphite or plumbago, which is almost pure carbon. It would appear that we cannot reasonably doubt the action of heat on these coals, for the plumbago is evidently a coal, changed by heat into its present semi-metallic appearance, and it is often produced in the furnaces of the arts by the action of heat upon carbon." The theory that anthracite, graphite, and bituminous coals are all of vegetable origin, and owe their present form to different degrees of heat and pressure, is in the highest degree rational, and well supported by facts.

Bituminous Coal Measures.

These differ chiefly from the anthracite coal measure in containing more frequent beds of limestone, marl, clay, and, perhaps, iron ore.

We cannot present a more intelligible view of the bituminous coal measures of the United States, than by giving the following *Section of the Carboniferous System of Ohio*, by Lieut. Mather.

Fig. 44



Feet.		
600	H	Upper coal series.
20	G	Calcareo-silicious rock.
400	F	Lower coal series.
80	E	Conglomerate.
300	D	Waverley sandstone series.
300	C	Slaty argillaceous rock, containing pyrites, &c.
600	B	Great limestone deposite.

"For convenience of description," says Mr. Briggs, "the above strata have been separated into seven groups or subdivisions, which, it is believed, correspond with important eras or changes during this deposition."

I. The first subdivision (marked B) includes the limestone of Adams and Highland counties, and is, probably, merely a continuation of that which forms the rocky strata of the whole western portion of the state. This limestone is of great thickness, and contains, where it has been examined, the petrified exuviæ of radiated and molluscous animals of marine origin, some of which belong to extinct genera.

and all to extinct species. These relics of a former condition of our planet are so abundant, that the conviction is forcibly impressed upon the traveller's mind that he is treading upon the floor of an ancient ocean. Many ages must have elapsed, and a peculiar condition of our planet prevailed, during the deposite of this vast mass of carbonate of lime, as it is composed of numerous layers extending to the depth of more than 600 feet, and contains throughout its whole extent myriads of petrified relics of animals, many of which must have lived and died where we now find them entombed.

II. In this division (marked C) there appears to have been an important change, not only in the materials which were deposited, but in their organic contents.

Reposing upon the limestone already described, occurs a body of argillaceous slate, 200 to 300 feet in thickness, in which animal remains are rare. This slate is thinly laminated, and, according to the rules of geological interpretation, must have been deposited at successive intervals in quiet waters.

III. The rocks superimposed on the argillaceous slate (D) appear to have been deposited under conditions no less remarkable than the two preceding divisions. Instead of the uniformly tranquil state of the two preceding periods, the strata bear evidence of having been formed in waters alternately quiet and disturbed. Under these circumstances were deposited the whole series of this division, which consists of alternate layers of fine-grained sandstone and slate, attaining a thickness of not less than 300 feet. The layers of sandstone appear to have been formed in a gradually shoaling bay, estuary, or sea, for they are characterized by ripple marks, which, it has been stated by Mr. Conrad, can only be made in shallow water. These markings are sometimes so surprisingly regular and beautiful as to appear artificial rather than natural, slightly resembling the flutings on some ornamental columns. But, in proof of this, reference need only be made to the aquatic vegetables which are found on the surfaces of some of the layers, and which were apparently entombed in the place of their growth.

IV. Resting on the alternations of sandstones and shales, occurs a stratum (E) which was formed under conditions widely different from those which prevailed during the deposition of the strata which have been mentioned. It consists of coarse silicious sandstone and conglomerate, both of which frequently pass into each other, according to the variable velocities of the waters in which the materials were deposited. That part of the stratum which is conglomerate is composed principally of quartzose sand and pebbles, the latter of which are variable in size, from a pea to two or three inches in diameter. These materials are partially united, sometimes with iron, and at others, it would appear, merely by adhesion; the pebbles are rounded by attrition, and strongly resemble shingle on the seashore. These pebbly materials were doubtless deposited by currents of water of unequal velocities, but sufficiently strong to move them onward and distribute them over an area of vast extent, leaving the sand in one place, the gravel in another, and the coarse pebbles in another, and so on; thus producing the various changes which we now observe, and causing the stratum, even in short distances, to pass from sandstone to fine conglomerate, and from the latter to one very coarse in its texture. This deposite was probably made in the vicinity of dry land, as near its junction with the strata of the third division are found the remains of a few terrestrial vegetables.

V. Superincumbent upon the conglomerate is a series of deposites (F), which indicates another important era or change. In the preceding period were strong currents of water, depositing only coarse sand and pebbles; in this the waters were less disturbed, and often tranquil, and so varied and charged with materials as to produce layers of sandstone, limestone, shell, coal, and iron ore; thus forming a series of strata some hundred feet in thickness, containing rich supplies of the most useful substances for the necessities and comforts of man. During this period must have flourished extensive forests of terrestrial plants, as we find their remains scattered with great profusion through the whole of this series of strata.

VI. The next division (G) is a rock only a few feet in thickness, but so remarkable in its character, so continuous, and requiring conditions for its promotion so widely different from those of any other rocks in the state, that it deserves special attention. This rock has been called *buhr*, from its strong resemblance to the buhrstone of the Paris Basin, and its use in the construction of millstones, to which both have been applied. This rock is chiefly composed of silex, but it occasionally contains some calcareous matter. Unlike others of which we have spoken, it seems to have been a deposition from waters containing the materials in chemical solution. It is characterized by the remains of molluscous animals.

VII. This division (H) includes the series of strata above the buhr. It consists of alternations of sandstone, limestone, shale, coal, and iron ore, and may be considered the upper member of the coal formation.

Dr. Hildreth, in his late report on the Geology of Ohio, has given a section of 35 distinct strata, which lie above the calcareo-siliceous rock marked G in the above cut, consisting of sandstones, shales, limestones, clays, iron ore, and four beds of coal, altogether amounting to a thickness of over 600 feet

Section of the Coal Strata on Kenawha River, Ohio.

By Dr. Hildreth.

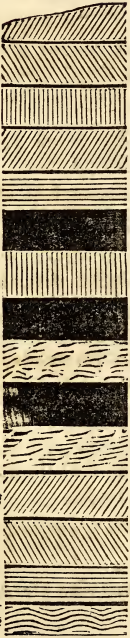
Fig. 45.

1. *Sandstone* — coarse-grained, containing fossil trees.
2. *Argillaceous iron ore*—1 foot thick.
3. *Slate*—silicious, used by Indians for arrow-heads.
4. Coal—bituminous, 4 ft. thick.
5. *Sandstone*—coarse, 150 feet thick.
6. Coal—bituminous, 4 ft. thick.
7. *Sandstone*—argillaceous, containing an abundance of vegetable impressions, 200 feet thick.
8. Coal—20 inches thick.
9. *Shale*—bituminous and slaty, with sand, 40 feet thick.
10. Coal—6 feet thick.
11. *Sandstone rock*—compact, 60 feet thick.
12. Bed of the Kenawha river.

U

Section of Coal Strata at Wheeling, Va.

Fig. 46.

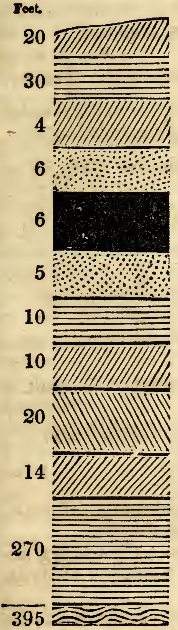


Feet.	
10	1. *Yellowish clay.*
12	2. *Sand rock*—argillaceous and slaty.
6	3. *Silicious rock*--resembles hornstone.
14	4. *Clay*, or argillaceous deposite, with nodules of limestone.
12	5. *Sandstone*—fine-grained, used for grindstones.
2	6. COAL.
24	7. *Limestone rock.*
2	8. BITUMINOUS COAL.
1	9. *Slate clay.*
7	10. COAL.
8	11. *Slate clay.*
1½	12. *Limestone rock.*
25	13. *Sandstone rock.*
60	14. *Slaty clay.*
182½	15. Bed of Ohio river.

NOTE.—A mile and a half from this section, a bed of coal 12 feet thick crops out from the side of a hill at such an angle of elevation, that, were it continued, it would be at the height of 200 feet above stratum No. 1 of the series !

Section of Coal Hill, Pittsburg, Pa.

Fig. 47.

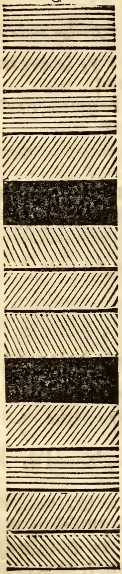


1. *Reddish brown argillaceous earth.*
2. *Sandstone*—slaty, fine-grained, ash-coloured.
3. *Shale*—dark brown, carbonaceous, slaty.
4. *Clay*—dark-coloured, carbonaceous.
5. Coal — bituminous; supplies the manufactories of Pittsburg.
6. *Clay*—dark, slaty.
7. *Sandstone.*
8. *Limestone*—dark-coloured.
9. *Sandstone*—light-coloured and argillaceous, with impressions.
10. *Limestone* — light-col'd, hard, compact.
11. *Sandstone*—fine-grained, compact, good building-stone. Salt water is obtained by boring through this rock.

Ohio River.

Section of the Rock Strata at the Salt-works at Kis kiminitas, Ohio.*

Fig. 48.



Feet.	
10	1. *Yellow argillaceous soil.*
20	2. *Sandstone rock*—slaty, friable.
116	3. *Sandstone rock* — argillaceous containing vegetable relics.
12	4. *Shale*—bituminous, slaty.
5	5. Coal.
10	6. *Slaty clay.*
160	7. *Sandstone.*
10	8. *Shale*—black and bituminous.
3	9. Coal—bituminous, compact.
10	10. *Slaty clay*—carbonaceous.
80	11. *Sandstone rock.*
4	12. *Limestone rock*—carboniferous, containing fossils.
60	13. *Sandstone rock* — hard, argillaceous. Forms bed of river.

The lowest members of this thick series of the carboniferous strata of the Alleghany range, as we have already remarked, are generally red, green, and buff-coloured sandstones, often very argillaceous, the whole having a probable thickness of 1000

* These sections are taken from Silliman's Journal, and were drawn up by Dr. Hildreth, of Ohio.

feet. The red variety predominates, and especially towards the base of the series. Resting upon these are massive strata of very coarse quartzose conglomerates and sandstone, which, in a thickness of a few hundred feet, generally constitute the verge or summit of the mountain table-land. Upon these beds again repose the bituminous coal measures, consisting of white sandstones, very analogous to some of those above mentioned, intermingled with other varieties of the rock, more argillaceous, and with yellowish, gray, pink, and even red sandstones in almost endless alternation. What strongly characterizes this whole class of deposites is the disproportionate amount of quartz or sandstones, and the paucity of slates and shales associated with the coal. The coal-seams are usually first met with soon after we pass the eastern verge of the plateau, and here the coal measures are mostly sandstones. Farther west we find the rocks becoming more argillaceous, enclosing their beds of soft shale and clay, and their irregular bands of limestone. The secondary rocks abound both in salt and gypsum.

The above sections will serve to illustrate the nature of the rocks and beds which contain coal in the United States, and may answer as a useful guide to such as are about to explore in search of this mineral. They clearly show that there is a very great similarity in the formations containing it; and a practical geologist can generally arrive at a very safe conclusion, whether the mineral may be sought with confidence, or the contrary, in any given locality.*

Millstone Grit and Shale.—This is the uppermost of the secondary rocks, and is composed of angular fragments of quartz and feldspar, held together by a hard argillaceous cement. The shale differs

* For an account of the extent of American Coal-fields, see the chapter on the "Mineral Resources of the United States."

from clay slate by being an aggregate of mineral particles, instead of being wholly made up of a single mineral species. These two rocks alternate with each other without any determinate order. They sometimes lie *below* as well as *above* the coal measures, as will appear by examining the sections above given. This group is sometimes very rich in metallic ores, such as lead, copper, mercury, iron, zinc, and manganese, which occur in detached spots, in nodules or beds, but never in veins. We also find in the grit phosphate of lime, fluor spar, sulphate of baryta, &c.

In Whitely county, Kentucky, the millstone grit is cut through by the Cumberland River to the depth of 700 feet; the conglomerate part being about 500 feet thick, and the shale, with three horizontal good veins of bituminous coal, each from three and a half to four and a half feet thick, being about 200 feet. Near Cumberland there is a fine exhibition of this rock, in an escarpment between 800 and 900 feet high. The millstone grit also abounds in the State of New-York, and we find it throughout Herkimer and Oneida counties, with a thickness of 30 or more feet. It seems to be composed of rolled stones or pebbles, and the brine-springs lie above it.

It may be stated, then, as a general fact, that the Blue Ridge System contains no coal; the Appalachian System contains the anthracite; and the Alleghany the bituminous coal measures, which also spread to the west over an immense area, and are traceable, as a single geological formation, far beyond the Mississippi.

Mr. R. C. Taylor, a practical engineer and geologist, has offered some considerations to show that it is very improbable, as Mr. Featherstonhaugh and others expect, that coal will be found in any quantity in the State of New-York; and Mr. Hildreth remarks that, with the exception of the Susquehanna and its tributaries, and Will's Creek, emptying into the Potomac, "all the streams rising in the great coal-field west of the mountains flow into the lakes or into the Ohio River, and, consequently, the ground falls off or declines in that direction, and becomes too low (as is generally supposed) to contain the coal measures. Its northern termination or boundary may be traced from the Tonewanda Creek almost in a direct course west to the Ohio state-line." "There would need," says Mr. Taylor, "a total height of mountains of 5120 feet, at the state-line between New-York and Pennsylvania, to contain the coal measures, whereas the hills there are probably below 600 feet in altitude."

The scientific corps at present engaged in the geological survey of the State of New-York, coincide with Mr. Taylor in the opinion that coal is not to be looked for to any extent in this state, as its rocks are supposed to be of a much earlier date than those of the coal measures of Pennsylvania and Ohio. But it should be recollected that coal is not restricted to any particular period, although circumstances at particular periods may have contributed to its greater accumulation. Thus we find it in mica slate at Worcester; and in Mansfield, Mass., a bed of anthracite ten feet thick has lately been discovered in a graywacke rock; and in Rhode Island, anthracite is also found in the same rock, forming a vein 14 feet wide. Now there are numerous localities of both anthracite and bituminous coal throughout almost the whole series of the transition rocks of this state, though hitherto they have been discovered in only small quantities. From the highly bituminous character of many of our rocks, and the frequent occurrence of petroleum or liquid bitumen, it would appear, at least, highly probable, that beneath these same rocks beds of coal may exist, though it does not necessarily follow. As our rocks, however, are chiefly intermediate between the graywacke, which forms an extensive formation in Ulster, Montgomery, and Sullivan counties, and the earlier coal-bearing strata of the Ohio Valley, we deem it improbable that coal will be found in very large quantities in this state.

In Europe, anthracite has been discovered in almost every rock, from lias, which lies above the new red sandstone (which latter rests immediately on the proper coal measures), to *gneiss;* and bituminous coal occurs in the oolitic and new red sandstone series, as well as in the coal measures. An extensive coal-field in Scotland is contained in the lias rock; and Humboldt, Daubuisson, and other able geologists, consider the red sandstone group and the coal measures as belonging to the same formation. All the facts on this subject show that the coal-beds occur at very unequal intervals, and that the causes which produced them have acted irregularly, and that it is a hasty generalization, as Professor Hitchcock observes, which would limit workable coal to the coal measures. This able geologist accordingly, so far from discouraging explo rations for coal in the new red sandstone of the Connecticut Valley, which is probably equivalent to a similar formation in this state, actually recommends them.

Geologists in this country have been too much in the habit of instituting a comparison between our coal-bearing strata and those of Europe, or of making the carboniferous group of England the criterion by which to judge of the existence of coal here. But, from what we have stated, the reader will perceive that it is doubtful whether the same rocks, or precisely the same order of superposition, are anywhere traceable: all such speculations are based on the hypothesis of universal formations, a doctrine as yet far from being established.

CHAPTER XXIII.

GEOLOGY OF THE UNITED STATES.

UPPER SECONDARY FORMATIONS.

(*Supermedial Order. Cretaceous, Oolitic, and Sandstone Groups.*—De la Beche. *Saliferous System.*)

Upper Secondary.—Division.—How Distinguished from Tertiary.—New Red Sandstone.—What it Includes.—Its Range and Extent.—Oolite.—Green Sand.—Equivalent to Cretaceous Group.—Its Fossils.—Its Range and Extent.—Mode of its Formation.—General Results.

The rocks of this formation, we have already stated, are divided into four groups, viz.:

1. Cretaceous or Chalk.	3. Green Sand.
2. Oolitic.	4. New Red Sandstone.

This group of strata is easily distinguished from those of the tertiary, not only by their chemical character and greater compactness in their mechanical structure, but also by a marked difference in their organic remains, and by a want of conformity in this strata, as they are rarely parallel to those of the tertiary, and also exhibit greater evidence of having been disturbed and changed from their original position. The organic remains in this formation are also mostly petrified; in the tertiary they generally are not. The first three of the series are evidently of marine formation.

New Red Sandstone.—According to our arrangement, proceeding upward, we find, next to the millstone grit, the *new red sandstone,* so called because supposed to be of later formation than that already described under the name of *old*. It is also called variegated sandstone and red marl, and is one of the most extensive rocks in Europe, being the site of the salt-mines of Cheshire and Poland, and of the mercury of Idria. Although rock-salt and gypsum are found both in the secondary and tertiary strata, yet their occurrence is regarded as most characteristic of the new red sandstone. They thus occur in Europe; and in Cheshire (Eng.), 42 yards below the surface there is a bed of salt 26 yards thick; and below this there is another bed, which has been sunk into 40 yards without penetrating through it.

What is called new red sandstone is a very miscellaneous rock, or, rather, group, being made up of

1. *Psammite*, a rock composed of quartz, with an argillaceous cement, coloured red by oxide of iron
2. *Red marl*, or, as it is called in Jersey, *red shale.*
3. *Bituminous* and *Carboniferous Shales.*
4. *Conglomerate*, composed of pebbles of quartz, feldspar, and rounded fragments of older rocks, cemented by a red clay.
5. *Red Clay.*
6. *Gypsum.*
7. *Rock-salt.*
8. *Magnesian limestone.*

It contains, besides, beds of lignite (coal), iron ore, strontian, barytes, manganese, cobalt, bismuth, copper, lead, &c.

It is yet in dispute among geologists whether the new red sandstone, or a rock equivalent to the new red sandstones of the Old World, does exist in this country. We have already stated the reasons which induced Professor Hitchcock to consider the sandstone of the Connecticut Valley as belonging to this formation, and in our judgment they are satisfactory. In our own state there seems to be great uncertainty in relation to the date of our sandstone rocks, and our geologists have not identified any of them as belonging to the new red formation. As there are numerous brine-springs in the red sandstone of Oswego, and extending west to the Niagara River, this circumstance would seem to lend great probability to the opinion that this rock is equivalent to the new red sandstone of Europe. But whether this be so or not, the formation which we designate as the new red sandstone occupies a narrow belt of country, ranging for many miles up the valley of the Connecticut River, comprising red, soft argillaceous shales and harder red sandstones, and, near the top of the series, a coarse, variegated conglomerate, made up of a vast assemblage of pebbles of primary and other rocks. In various places Professor Hitchcock has observed the marks of extinct and gigantic races of birds of the wading class deeply impressed in this rock in various places; also fossil remains of fishes of different species. In New-Jersey we find the same formation bounded on the southeast by the Hudson River, Staten Island Sound, the Raritan River from its mouth to the mouth of South River, and from thence by an irregular line to Trenton, thus embracing the southeastern portions of Hunterdon, Morris, and Bergen, together with the whole of Somerset, all Essex, and a portion of Middlesex counties. The strata repose directly on granitic gneiss, and consist, in the ascending order, of alternating red conglomerates, sandstones, and shale, surmounted by a coarse, variegated, calcareous conglomerate. From New-Jersey we trace this formation across the Delaware into Bucks county (Penn.), and across the Susquehanna, below Harrisburgh, into York county, and so on through Frederic county, Maryland, to the Potomac River in Virginia.

Recent explorations in Virginia have also brought to light an extensive group of sandstone strata, which we shall refer to this system, extending from the Potomac River, near the mouth of Occoquan, in a direction a little west of south, to the Rappahannock, and thence south across the State of Virginia. It occupies a narrow belt, in some places only a few miles wide, resting upon the eastern edge of the primary region, as it does in New-Jersey, and disappears beneath the tertiary beds of the Atlantic plains. It is called freestone, and often is fine-grained and compact, forming a good building-stone, for which it has been employed for public edifices in Washington City. Its fossils are exclusively vegetable, and of entirely different species from those which characterize the coal formations. The nature of the fossil remains would seem to refer the above rock to the period of the oolite group of Europe, but we choose to consider it as the upper series of the new red sandstone formation

Oolitic.

The next division of the upper secondary rocks is the oolitic. Limestone rocks, having an oolitic structure, have been found in several places in the United States, as at Warwick (N. Y.), Saratoga, Schoharie, Easton (Pa.), Franklin (N. J.), but they are not regarded as equivalents to the European oolite, either in respect to position or organic remains.

Green Sand and Cretaceous Groups.

The next group in this ascending series is the green sand, which forms a belt on which the tertiary rests, extending from Sandy Hook to Georgia. With this, however, we shall describe the strata of the cretaceous period, so called, as it seems impossible to separate them. The true chalk has never been discovered in this country; yet, from the character of the fossil remains, some of our best geologists consider the green sand group as identical with the cretaceous formations of Europe. Of these fossils there have been found over 100 species of animals; of which seven are of the class of large *reptiles*, including three species of *crocodile;* two belong to *fishes*, one to a *tortoise*, and one to a *wading bird;* while of the other fossils, upward of 65 are remains of *shell-fish*, *corals*, and other marine tribes low in the scale of beings. Not a single one of these fossils can be traced to belong to anything living in the present day, and but one of these is common to the deposites of both continents. Still there is a generic relationship among the fossils of both deposites, although a striking want of identity between the species; and this is sufficient to determine the place of the green sand to be somewhere among the secondary rocks, though it does not appear very evident whereabout in the secondary series of Europe they should belong.

Fossiliferous strata, referrible to the newest secondary or cretaceous period, occur in New-Jersey, Delaware, Maryland, North and South Carolina, Georgia, Alabama, Mississippi, Tennessee, Louisiana, Arkansas, and Missouri. It is this which forms the "marl tract" or green sand strata of New-Jersey, called marl, not from its resemblance to this substance, but from its peculiarly enriching properties to the soil. This formation may be said to cover the whole southern half of the state, bounded by the lower edge of the rocky strata which lie between Trenton and Perth Amboy. A line drawn from a little below Trenton to the western side of the Sand Hills, and from thence prolonged to Amboy, will cut off that southern portion of the state which is underlaid by the green sand. From New-Jersey the formation stretches across the State of Delaware, and into Marlyand as far as the Sassafras River on the eastern shore. Rocks of the same secondary period, but of a different mineral character, appear at Ashwood and Wilmington, on the Cape Fear River, in North Carolina; and in South Carolina they are again seen on Lynch's Creek, and on the Pedee and Santee Rivers, as well as in the region west of the city of Charleston. Farther south, they occur in Sandersville, in Georgia; and they occupy a large extent of country in Alabama. The same strata cover nearly the whole state of Mississippi, and also abound in the southwestern portion of Tennessee, Louisiana, between the Alexandria and Natchitoches, and on the Washita River, and in Arkansas on the calcareous platforms of Red River. But, though these cretaceous formations belong to the same period, yet the northern and southern sections present very marked differences of mineral and fossil constituents. The northern, or green sand formation, may be said to extend through New-Jersey and Delaware, to the eastern shore of Maryland, over a nearly horizontal plain, the mean elevation of which above the sea is not more than from 40 to 60 feet, though in the northeast of Monmouth it rises 300 feet above the sea. It consists of strata of a friable material, more or less arenaceous or argillaceous in its texture, of a dark greenish or bluish colour, including bands or layers rich in a peculiar fossil, and characterized by a thick bed of green sand, or, as the inhabitants term it, *marl*. The northern and western portions of the newer secondary or cretaceous formations consist of limestone of various degrees of hardness, more or less abundant in fossils, and having the particles of green sand only sparsely disseminated through the mass. These limestone strata, which thus compose nearly the whole of the cretaceous group in the Southern States, exist on a scale of vast extent and thickness, rising into bold, undulating hills, resembling the surface of the chalk in Europe.

The "marl" or green sand stratum contains, often as its sole ingredient, a peculiar mineral, in the form of small dark grains, about the size of grains of gunpowder. Their form is roundish, and they are very often composed of two or three smaller grains united together; a distinctive feature by which they may at once be recognised from other dark kinds of sand. Though they contain on the average about 50 per cent. of silica (the basis of flint), they are not gritty, but can be readily bruised between the teeth or upon the nail; and some varieties, when moistened, admit of being kneaded into a half plastic mass, like impure clay. The prevailing colour of the grains is a *deep green;* often a dull greenish blue, and not unfrequently a black chocolate colour. After having been exposed to the air for some time, this "marl" contracts a light gray hue, from the exterior grains becoming coated with a white inflorescence, which proves to be carbonate and sulphate of lime. The following analysis, by Mr. Seybert, gives a fair average of the composition of the green grains: silica, 49.83; alumina, 6; magnesia, 1.83; potash, 10.12; protoxide of iron, 21.53; water, 9.80; loss 0.89 = 100 grains. Some specimens contain as much as 5 per cent. of lime. The green sand forms a deposite over the whole southern part of New-Jersey of from 20 to 40 or more feet in thickness; and as it is one of the most fertilizing agents, when applied to the soil, hitherto discovered, its value will be readily understood. A mine of gold would be of far less value to the state than its inexhaustible beds of "marl." The diversified deposites of sand, clay, green sand, limestone, and sandstone composing the cretaceous series in New-Jersey,* assume a great variety of aspects, resulting from their almost endless intermixture and their various degrees of induration. The most fossiliferous beds are those consisting chiefly of the green sand, and next, the thin calcareous stratums.

* Report of Professor Henry D. Rogers to the Legislature of New-Jersey.

Green sand has lately been found by Professor Hitchcock in Marshfield, Massachusetts, and he thinks it abounds in Barnstable and Plymouth counties; but as it occurs among primitive rocks, and, besides, contains no potash in its composition, which is a constant ingredient in the green sand of New-Jersey, it is very doubtful whether it ought to be classed in this formation. At any rate, it will prove of little value, if, as Prof. Rogers supposes, the fertilizing properties of this mineral are owing to the *potash* contained in it. That such is the fact there can be no doubt whatever.

The character of its fossils, as well as its mineral contents, proves that the secondary cretaceous formation has been deposited upon the bed of the ocean in places where the sea encompassing the coast was *shallow*, like that which now exists over the wide belt of shoals and soundings in front of our Atlantic coast. This is shown by the habits of the animals whose remains are found, and the tokens of land, derived from the coarseness of the sands, as well as the remains of terrestrial vegetation. Prof. Rogers considers the green sand as a *chemical precipitate*, thrown down from solution in the waters of that ancient sea, and not a sediment of sand mechanically carried out from land, as must have been the case with the silicious sands adjacent to it. And here is an important problem for the chemist: required the conditions necessary to precipitate such a deposite in comparatively so short a space of time.

The rocks which we have thus attempted briefly to describe in this and the last chapter, constitute the great secondary formation of the United States, which is bounded by the irregular border of the transition series already described, extending from between the Alabama and Tombigbee rivers to Fort Ann, near Lake Champlain. On the northwest it follows the shores of the great lakes, and loses itself in the alluvial of the great basin of the Mississippi, occupying a surface of from 200 to 500 miles broad, and extending, in all probability, west of the Mississippi to the foot of the Rocky Mountains. We find it commencing near the head of Lake Champlain, skirting the east side of the lake, seldom extending over half a mile from the edge of the water, containing shells and flints. When it reaches the south extremity of the lake near Whitehall, it spreads out across the northern point of the state of New-York, striking the head of Lake Ontario at the Thousand Islands, and spreading over the whole of Western New-York, and Western Pennsylvania and Virginia, and occupying the whole surface of the Middle, Western, and Southern states. It also occupies that belt in the Connecticut Valley and along the Atlantic coast which we have described as belonging to the new red sandstone; also the green sand and cretaceous groups.

CHAPTER XXVI.

TERTIARY FORMATION.

Superior Order (Conybeare). *Supracretaceous Group* (De la Beche).

Tertiary.—How distinguished from other Formations?—Mr. Lyell's Division.—Pliocene, &c.—Its Range and Distribution.—Professor Hitchcock's Arrangement.—Plastic Clay.—Tertiary in State of New-York.—Ancient Arm of the Sea.—How Drained.—Newer Pliocene of the United States.—Older Pliocene and Miocene Formations of the United State.—Eocene do.

This group has but lately been erected into a distinct formation, as the strata assigned to it were so loosely aggregated that they were supposed to be of modern origin, and, in fact, merely alluvial.

Its organic remains distinguish it from the secondary formations, and its layers mark its difference from the alluvial and diluvial deposites.

We have already stated that this formation is divided into three groups, called by Mr. Lyell *pliocene*, *miocene*, and *eocene*, distinguished by the character of the shells of molluscous animals which they contain. In the pliocene formations, more than one half the shells belong to existing species; in the miocene, less than half; and in the eocene, the proportion is still less. In Europe this group contains at least fifty species of terrestrial animals, none of which belong to existing species, 100 species of fish, and several of extinct birds and reptiles.

The tertiary formations yet known to us are confined almost exclusively to the Atlantic plain of the United States, and to the southern part of the Valley of the Mississippi. The northern limit of this formation has generally been supposed to be in the southeastern corner of New-Jersey, adjacent to the Delaware Bay. But it is now known that they exist in every state of the Union. Prof. Hitchcock has described the tertiary of Massachusetts under two divisions. *The first*, which he calls the *most recent*, consists of horizontal alternating layers of white silicious sand and blue plastic clay, the sand occupying the highest place in the series, and covering most of the surface. The sand and gravel are often several feet thick, their upper portion being disturbed and piled up irregularly by diluvial action.

The most extensive deposites of this class are in the Valley of the Connecticut, though they extend in patches all over the state. These clay beds are often of great thickness. In Deerfield they are over seventy feet thick, and covered by sand fifteen or twenty feet deep; while in the vicinity of Boston the same clay is from 70 to 120 feet thick

This deposite contains hydrate of iron, and but few organic remains.

The second division embraces the *plastic clay.* This is well exhibited at Gay's Head (Martha's Vineyard), and consists, in general, of interstratified inclined layers of gravel, conglomerates, sands, variegated clays, iron ore, and lignite. These clays and sands are of different colours and texture, and contain shark's teeth, crocodile bones, and other organic remains.

Some of the remains of a shark were discovered at Gay's Head, which Professor Hitchcock estimates to have been from thirty to fifty feet long. This result corresponds with the conclusions of European geologists, that the extinct animals were much larger than those now existing, and that all climates were of a tropical character. The lignite (coal) which occurs in it forms beds sometimes several feet thick, or is mingled with the clay in comminuted dark masses, resembling peat, through which logs are interspersed. Sometimes the woody fibre is very distinct.

The *plastic clay* formation, distinguished by interstratified lignites with amber, and the relics of marine animals and terrestrial vegetation, lies immediately above the green sand formation, which is the equivalent of the chalk of Europe, though wanting in this country, and extends from Cape Cod to the borders of the Gulf of Mexico.

In the State of New-York the tertiary formation forms a deposite from the head of Lake Champlain to its outlet, extending about four miles from the lake on the west side, and from six to twelve miles on the east, interrupted, however, occasionally by primary rocks, which jut up against the lake shore. It forms a bed averaging twenty-five feet thick, composed of clays and sands, and embracing marine shells or relics of a very recent date. The tertiary extends above the level of the lake about 200 feet.

The tertiary also forms a deposite in the counties bordering both sides of the Hudson, from its source to the Bay of New-York, furnishing inexhaustible beds of clay for the making of bricks and pottery. This section of country is universally believed by the inhabitants to have once formed the bed of the ocean, and the late Dr. Mitchill and others have supposed that it was drained by the bursting of the Hudson through the Highlands at Newburgh. But it is very evident that this region was covered by salt water, and an arm of the sea could never be drained in this way, though a lake situated above tide-water might. Neither was it a salt-water lake above tide-water mark; for the summit line of the Champlain Canal is only 147 feet, and the tertiary extends 200 feet above the lake, and the present level of the lake being only 93 feet above tide-water. As the tertiary marks the limits of the ancient water, it is evident that, rising 200 feet above the lake, it must have communicated with the sea by the St. Lawrence Channel on the north and the Hudson on the south, thus converting it into an arm of the sea.* The only rational way to account for the draining of this extensive tract, as well as many other similar ones in our country, is to suppose the land to have been formerly elevated by some force beneath. Such elevations will also account for the numerous floods which have at different times swept over the surface of the earth; and it is by no means improbable that "Noah's flood" was caused by the upheaving of some extensive mountain range, for we are told that "the fountains of the great deep were broken up."

The tertiary strata of the United States are now ascertained to belong to all the four periods into which Mr. Lyell has divided this formation, viz.,

* E. Emmons.

the newer and older pliocene, the miocene, and eocene periods.

The newer Pliocene.—Mr. Conrad has pointed out a distinct deposite of this formation in Maryland. It is well characterized about three miles north of the low sandy point which forms the southern extremity of the peninsula near the mouth of the Potomac. Here the bank rises to an elevation of some fifteen feet at its highest point, and the fossils are visible to the extent of a quarter of a mile. The stratum consists of sand and clay, disposed in horizontal beds, with an abundance of shells similar to existing species. The distance from the nearest point on the Atlantic Ocean is about 45 miles, but nearly 100 miles by the course of the bay. The extent of this formation is not known.

Older Pliocene and Miocene Formations.—These tertiary beds show themselves in a wide and, at present, an undefined belt in the southern extremity of New-Jersey, and extend through Delaware, Maryland, Virginia, and North Carolina, in the southern part of which last state, and in part of South Carolina, they only occur in interrupted patches, thinning out and disappearing altogether after reaching the Santee River in South Carolina. In New-Jersey, Maryland, and Virginia, the proportion of recent to extinct species among the fossils hitherto discovered does not, in the average, exceed 20 to 25 per centum, which, therefore, places their origin in the *miocene* era. While the fossils south of Virginia show that the southern portions of the tertiary deposites belong to the older pliocene era. South of Virginia the tertiary beds contain nearly *two thirds* recent species, while north of that limit they contain a less proportion of living species than *one fifth*. The total number of species of shells found in our miocene formation is about 200, 40 of which only are living shells, and inhabit the adjacent coast.

The miocene beds usually consist of sands and clays of various colours and characters, having much oxide of iron often mingled with the earthy matter, giving it a yellow or brown appearance, especially the upper strata. The lower strata are generally composed of a green silicious sand and a bluish clay, soft and tenacious, arranged in horizontal layers. This is often called *blue marl*, and contains an abundance of brittle, shelly matter, which proves a valuable manure in sandy soils. Throughout the whole of these beds there is disseminated an abundance of greenish-black grains of the green sand, already described as belonging to the cretaceous formation of New-Jersey.

Eocene Formations.—This oldest division of the tertiary extends along the western limit of the Atlantic Plain, in a belt of from 10 to 20 miles broad, between the primary and secondary rocks and the miocene strata, from beneath which the formation in question rises westward with a very gentle inclination. Going south, we first strike it in Maryland, between the Chesapeake Bay and the Potomac River, as at Fort Washington. Its eastern limit crosses the Potomac near Matthias's Point, and pursues a course almost due south, crossing the James River at Coggin's Point, and thence stretching on south through all the Southern states to Alabama, where it forms an extensive deposite. Our description of the miocene beds will also apply to this formation, as it is also composed of a loose mixture of various coloured sands and clays, abounding in ferruginous matter and green sand. The total number of eocene shells hitherto discovered is about 230, not one of which is common to the miocene formation, nor now exists, or can be referred to any recent species. In Europe, however, out of 1238 species belonging to the eocene, 42 are common to the miocene. Another interesting fact is, that out of 210 eocene species from Alabama, not more than six are found in the same formation in Europe. This deposite is also called *marl*, and is extensively used in Virginia and other states for its fertilizing properties.

CHAPTER XXV.

GEOLOGY OF THE UNITED STATES.

BASALTIC AND VOLCANIC ROCKS.

Basaltic and Volcanic Rocks.—Evidences of Volcanic Action in the Rocky Mountains.—Trap Rocks.—Bakewell's Definition of Basalt—Of Greenstone.—Localities of Greenstone Trap—In Massachusetts — New-Jersey — Columbia River — Nova Scotia.

"The principal deficiencies in the geological formations of the United States," says Professor Silliman, "are in the absence of active volcanoes, as well as most of the members of the upper secondary. However delightful active volcanoes, with their earthquakes and eruptions, may be to speculative geologists, the sober, unscientific population may well rest quite contented without them, satisfied to barter the sublime and terrific for quiet and safety. Although the soils formed from decomposed lava are often fertile, and the vine flourishes, and the clusters smile most remarkably on the flanks and at the feet of the volcanic mountains of warm countries, these influences are too local to be of much importance to agriculture.

"Within the United States proper, including the states and territories beyond the Mississippi and east of the Alleghany Mountains, there is not, so far as we know, a single active volcano, nor even an unequivocal crater of one that is dormant. Both north and south of our limits there are, on the Pacific shores and the islands, numerous volcanoes; and it would be strange, indeed, if there were none within our extensive possessions on the same coast."

There are numerous evidences of volcanic agency among the Rocky Mountains, such as extinct craters, lava, scoriæ, and other igneous products. "The whole country," says Mr. Parker,* "from the Rocky Mountains on the east and Pacific Ocean on the west, and from Queen Charlotte's Island on the north to California on the south, presents one vast scene of igneous or volcanic action. Internal fires appear to have reduced almost all the regular rock formations to a state of fusion, and then, through fissures and chasms of the earth, to have forced the substances which constitute the present volcanic form. Such has been the intensity and extent of this agency, that mountains of amygdaloid and basalt have been thrown up; and the same substance is spread over the neighbouring plains, to what depth is not known; but, from observations made upon channels of rivers and the precipices of ravines, it is evidently very deep. The tops of some mountains are spread out into horizontal plains, some are rounded like domes, and others terminate in conical peaks and abrupt eminences of various magnitudes, which are numerous, presenting themselves in forms resembling pillars, pyramids, and castles. There are several regularly formed craters; but these, presenting themselves in depressions or in cones, are rendered obscure by the lapse of time. That volcanoes have existed there can be no doubt, but that they have been in active operation recently is more uncertain." Mr. Parker also states that nearly all the rocks among the Rocky Mountains are amygdaloid, basalt, lava, and obsidian (volcanic glass), which sufficiently prove the volcanic character of this region.

* Exploring Tour, &c., p. 208.

Basaltic Rocks.

The basaltic or trap rocks are not unfrequently met with in various parts of the United States.

The word *trap* (step) is usually applied to rocks in which hornblende predominates. It was formerly confined to basalt, properly so called. Some geologists now tell us that there is no real basalt in this country; and Cleaveland remarks, that "the columnar and prismatic masses which exist in various parts of the United States are a secondary basaltiform greenstone, which in some cases, perhaps, may be passing into basalt."

Bakewell states, that "when hornblende and feldspar are intermixed and have a granitic structure, they form what is generally called *greenstone;* and if the hornblende and feldspar, or augite and feldspar, are intimately combined and finely granular, they form *basalt*." It should be recollected, then, that the greenstone is composed of distinct grains, or small crystals of feldspar and hornblende, so united as to give it a granular appearance, while basalt is a compact homogeneous mass of the same ingredients. Whenever this class of rocks assume a trap or columnar form, as in the East and West Rocks, near New-Haven, we shall find them to be fine-grained, and, of course, basalt.

Greenstone trap occurs in the eastern and northeastern parts of Massachusetts in rather extensive ranges, being the prevailing rock that encircles Boston on the north, west, and south, after passing beyond the graywacke and argillaceous slate that encircle that city. In Charlestown particularly we often meet with beds of greenstone; also at Roxbury and Nahant, where it forms a vein 40 feet thick in argillaceous slate and syenite. In Weston, Waltham, Lincoln, Lexington, and West Cambridge, we find greenstone forming ridges, elevated some 500 feet above the ocean. A ridge of greenstone commences at West Rock, near New-Haven, and extends from thence almost in a direct line to Mount Tom, near Northampton, in Massachusetts. From hence it stretches north through the Connecticut Valley, in connexion with the red sandstone, and so on into Vermont and New-Hampshire, associated with argillaceous and mica slate. We also meet with ridges and beds of greenstone in other parts of Connecticut, and particularly east of the main ridge already described. The greenstone in the eastern part of Massachusetts is of a dark green colour, from the presence of epidote, while that in the Connecticut Valley exhibits a gray or iron-rust colour, from the presence of oxide of iron. It seems to be a fine-grained mixture of hornblende and feldspar; sometimes *columnar*, frequently *amygdaloidal** and *amorphous*.† The scenery of the Connecticut Valley derives its boldness, wildness, and beauty principally from the greenstone ridges that have been described. The Palisades, or Cloister Mountain, on the Hudson, near New-York, are basaltic greenstone: and, as we go west, we strike it again at Patterson, where it forms the Falls of the Passaic, and the First and Second Mountains; and, a little farther west, Freakness Ridge. A few miles south, and midway between the Hudson and the Delaware, we find it forming a considerable elevation near Somerville, called the Somerville Trap Ridge. A section of the state still farther south, striking through Trenton, presents several ridges of greenstone or trap formation, as at Goat Hill, Belle Mount, Smith's Hill, &c.; there being, in fact, a double or triple chain of trap hills extending north and south near the centre of the state, commen-

* From "*amygdala*," an almond. Any rock containing globular masses scattered through it, like almonds in a cake, is said to be *amygdaloidal.*

† From "*a*," without, and "*morphe*," form: destitute of regular form.

cing at Pluckemin, and running near the towns of Springfield and Patterson, approaching the primary region near Pompton. The rock varies from a fine-grained, compact basaltic trap to coarsely-crystallized greenstone, and contains, besides its essential components, *hornblende*, *feldspar*, and *augite*, various mineral ingredients, such as *epidote*, *prehnite*, *zeolite*, *stitbite*, *analcime*, and *datholite*. The trap rocks of New-Jersey evidently repose upon the general sandstone strata of the country, as may be ascertained by viewing the eastern base of the Palisades skirting the Hudson, or the bed of the Passaic River below the Falls at Patterson, or the Newark Mountains. "From what is now universally admitted," says Professor Rogers,* "concerning the igneous origin of trap, it is plain that over this portion of territory it has burst up in a molten state through a series of nearly parallel fissures in the strata, and after their consolidation and subsequent disturbance, which caused them to dip towards the northwest, and has overspread their adjacent portions without effecting any material change in their stratification, and producing only certain modifications in their mineral contents and structure." In some of the cliffs at Patterson, the greenstone assumes a columnar structure; and between it and the sandstone on which it reposes, we find an intermediate rock of six or eight feet in thickness, resembling toadstone or amygdaloid, holding nodular crystals of several minerals, *prehnite*, *analcime*, &c. Beneath this, a layer of the sandstone of a few inches thickness exhibits a baked appearance, and is full of small vesicular cavities, as if produced by the extrication of some gaseous matter or steam. The same appearances are common in the trap rock near New-Haven.

Trap rocks also occur in the State of Maine,

* Geol. Survey of New-Jersey.

about 100 miles above Hallowell, on the Kennebeck River, forming the summits of several mountains from 200 to 300 feet high. Here also it has a columnar structure, as at Mount Holyoke, near Northampton, and at Deerfield. The prisms present from three to six sides, their edges being straight and well-defined; and their general aspect is that of bricks standing on their ends.

Greenstone abounds also among the Rocky Mountains, where it is seen forming immense columns of a pentagonal form. "On examining the bluffs, or perpendicular banks of rivers and mountains," says Mr. Parker, "I have numbered from between ten and twenty different strata of amygdaloid, basalt, and breccia. These appear to be thrown up through dikes, or through craters rising in different succession one above another. In some places, the lowest formation was pudding-stone, above this amygdaloid, then a stratum of angular fragments of basalt and amygdaloid, and sometimes intermixed with lava,* which may be called breccia; and over these basalt, frequently in regular pentagons, which vary in size from one to five feet in diameter, and in regular articulated sections; and upon the basalt another stratum of breccia; and again upon these is superimposed another stratum of basalt, or in some cases amygdaloid; and, in the same manner, strata above strata, in some places to twenty in number. These strata vary in depth from a very few feet to thirty or forty; and the whole series rises from 200 to 500 feet."†

The accompanying plate, representing a ledge of greenstone rocks on the Columbia River, will convey a good idea of these formations. The channel of the Columbia in many parts is walled up on its sides, and studded with islands of basaltic rocks,

* Probably *trap tufa*, such as we have already described.

† Parker's "Exploring Tour beyond the Rocky Mountains," p. 220.

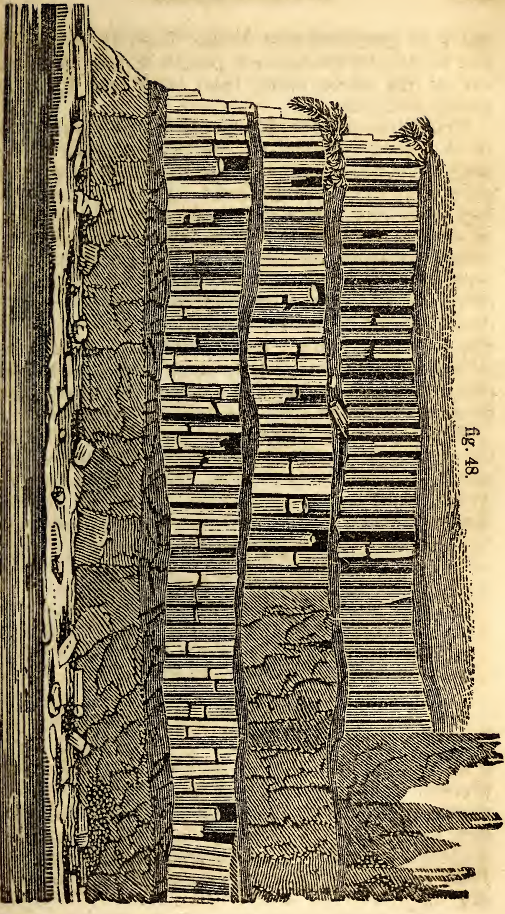


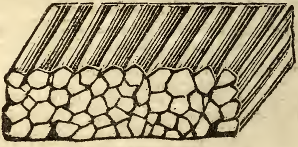
fig. 48.

BASALTIC FORMATIONS ON THE COLUMBIA RIVER.

rising in perpendicular height from 20 to 400 feet and below the cascades it passes through a mountain of the same more than 1000 feet high, and nearly vertical.

Extensive basaltic dikes exist in Essex county, in the northern part of the State of New-York, which pursue an easterly and westerly course to a great distance. At Avalanche Lake, a dike eighty feet wide cuts through Mount M'Martin nearly in its centre. Here we perceive on a large scale the effects of frost and water in breaking up the solid crust of the globe; there being numerous masses of rocks, from 50 to 100 feet long, broken up from their original beds, and carried partly down the declivity, constituting a mass of ruins from the base to the summit, which the rains and frost are constantly reducing to smaller masses, and urging them onward to mingle with the soil in the plain below.

What are called the natural walls of North Carolina are basaltic dikes, formed of columnar or prismatic masses, fitting close to each other, and lying with their lengths across the wall, and showing their ends on its sides as in the following sketch.



Basaltic Dike.

A trap formation, about three miles in breadth, extends along the Bay of Fundy, in Nova Scotia, a distance of 130 miles. It rises into stupendous precipices, and exhibits basaltic and greenstone columns 300 or 400 feet high, against which the waves and tides beat. This range affords a very great abundance of beautiful minerals, such as amethyst, rock crystal, chalcedony, agate, specular iron ore, &c

CHAPTER XXVI.

GEOLOGY OF THE UNITED STATES—(Continued).

ALLUVIAL AND DILUVIAL FORMATIONS.

Diluvium.—Causes of Diluvial Deposites.—General Deluge.—Existing Causes. — Diluvium of Cape Cod. — Alluvium. — Where Found.—Banks of Rivers.—Seas.—Lakes.—Long Island.—Dunes or Downs.—How Found.—Phenomena of.

Diluvium.—We have defined diluvium to consist of gravel, bowlders,* sand, and loam, and mixed confusedly together by powerful currents of water. Of course it occupies much of the surface throughout a great portion of the United States, and it is impossible, in a work like the present, to attempt to give a complete description of its localities. It has generally been attributed to the agency of a general deluge, and most geologists have formerly been willing to acknowledge that the phenomena connected with it might all have been occasioned by that described in the Bible. There are others, however, such as Mr. Lyell, who attempt to show that these phenomena might all have been produced by causes now in operation, and such as we have pointed out in our chapters on the destruction and formation of rocks, viz., rivers, rain, frosts, &c. This theory, however, is so little satisfactory, that we do not deem it necessary even to attempt to refute it. The hypothesis, however, that the phenomena in question are the result of different floods, produced by the elevation of rock strata at various

* Rocks and stones which have been transported from their original beds, and are, generally, more or less rounded by attrition and the action of the water.

periods, is far better supported by existing facts, and is probably that which will eventually be adopted by most geologists. Professor Hitchcock, who is a close and accurate observer, as well as philosophical reasoner, concludes, after the most thorough examination, that "all the diluvium, which had previously accumulated by various agencies, has been modified by a powerful deluge, sweeping from the north and northwest over every part of Massachusetts, not excepting its highest mountains; and that, since that period, none but alluvial agencies have been operating to change the surface."

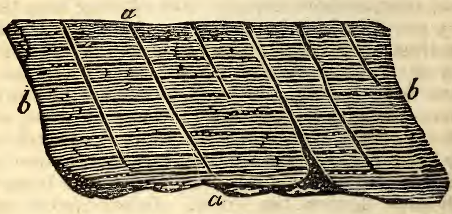
Every part of the United States, and we may say the same of northern and middle Europe, if not Asia, exhibits abundant evidence of a similar flood from the north; as shown by rocks and bowlders being generally found south of the ledges and strata from whence they were originally dislodged.

These bowlders are in some parts of the country strewn over the surface in immense quantities, and always correspond with the rocks lying north of them. They are found on the sides and tops of mountains, of a different species of rock from that which forms the mountain itself; and we know of no other cause but a powerful flood to explain the phenomenon. They are often of great size, frequently 20, 30, or even 40 feet in diameter, and occasionally they are so delicately poised upon another rock as to be easily moved. They are then called rocking-stones; and some, weighing over 100 tons, can be easily moved by the strength of a single man. No one can travel over New-England without being impressed with a full conviction that, at some former period, an immensely powerful current of water has swept over the land.

But it is not to be inferred that the diluvial formation is always level, or nearly so; on the contrary, it is often piled up into elevations whose surfaces exhibit curves of every description, while the corresponding cavities are of similar shapes, as in the following sketch:

Near Cape Cod, in Massachusetts, these elevations rise to a height of 200 or 300 feet, and are very numerous, giving to the country a hilly and even mountainous aspect. On digging into them, they are found to be composed of a loam, which has thus been piled up and scooped out by the action of water. Similar ones formerly existed on New-York Island, and over much of the surface where the city is now built. Some of these were 250 feet high, and made up of sand, gravel, and bowlders of greenstone, porphyry, serpentine, and granite; most of which evidently came from the Palisades across the river. Occasionally, also, masses of secondary limestone, containing fossil shells, were met with, which must have been brought from above the Highlands. Occasionally we meet with consolidated alluvium, composed of pebbles and, perhaps, masses of different kinds of slate, and consolidated together by a cement of iron or lime; which, having been dissolved in water, has thus been diffused through the mass. Such conglomerates are often called *pudding-stone.* The reader will now be able, perhaps, to form a correct idea of what is understood by diluvial; and he can readily perceive the mode of its formation, if he will suppose the agents which we have described as destroying rocks to have been in operation from the time the solid rocks were deposited up to the general deluge. Here were immense materials ready to become the sport of a deluge of waters, and to be worked into all the fantastic forms and shapes, by currents and counter-currents, which we actually find them to have assumed.

There is another argument of great weight, which proves that a powerful current from the north has swept over the country, and that is, the scratches, grooves, and furrows often to be seen on the surfaces of rocks that have never been moved from their place. These run south and southeast, and were evidently made by heavy stones moved over their surfaces. The following sketch represents such a rock in Massachusetts:



We have stated that some geologists attribute the diluvial deposites to the flood recorded in Scripture, and that they also attribute that phenomenon to the elevation of the strata. But if, as it is believed, the tertiary strata were deposited before the deluge, this could not have been the cause of that catastrophe, because the tertiary strata are horizontal, and must, therefore, have been deposited after the elevation of the solid rocks beneath, or they would have been raised and dislocated also. Accordingly, as Mr. Hitchcock states, there must have been an interval long enough between the elevation of the strata and the last deluge for the deposition of this tertiary formation. This must have required an immense period, because it is, perhaps, on an average, 150 feet thick; and if we judge from the present rate of filling up of our lakes with mud, it must have required many thousands of years. This, however, does not clash with the Scripture account of the creation of the world, but only with the common interpretation of it. We are nowhere told when "the beginning" was, when God created the earth; only that it was created in the beginning. How long a time was passed over in silence between "the beginning" and that period when the earth was reduced to its present state, and peopled with its present races of inhabitants, we are not informed.

Alluvium.

The surface of the earth, as we have already stated, is constantly undergoing changes. Rocks are crumbling; mountains disintegrating; hills wearing away; the banks of rivers, lakes, and the ocean disappearing; and the sand, gravel, clay, loam, and mud, when deposited from all these sources, constitute *alluvium*. We find such deposites chiefly on the banks of rivers, lakes, and the sea, in swamps and low grounds; and they constitute the richest and most valuable soil for the agriculturist. These alluvial tracts are, indeed, composed of the very finest materials, such as, from their suspension in water, would be carried to great distances, and their effect in enriching the soil may be estimated from the influence of the annual overflow of the Nile, which is looked for with the greatest anxiety by the inhabitants, as its absence is a pretty sure indication of a famine. In this country we have rich alluvial tracts bordering most of our rivers and streams, such as the Connecticut, the Merrimack, the Housatonic, the Hudson, the Susquehanna, the Delaware, the Potomac, the Ohio, the Mississippi, the Wabash, the Illinois, the Missouri, the Red River, &c. In many places the alluvial deposites are from 20 to 50 feet deep, and logs, leaves, and other vegetable and animal relics are dug up from that depth. The banks, however, are so much elevated by the gradual deposition of these deposites, that it is only during a time of flood or an unusual accumulation of water that they are overflowed. In some of them, as the Mississippi, the beds of the streams are also elevated by the same cause, so that the river is considerably higher than the adjacent country. This is not always the case; for Professor Hitchcock states that, since the Connecticut and its tributaries began to flow, they have excavated their beds nearly 100 feet, though the Connecticut at Northampton is still more than 100 feet above tide-water at New-Haven; so that its descent to the ocean is only at the rate of about a foot per mile. Where the descent, and, consequently, the velocity of the water, is greater than this, the bed of the stream will be excavated; where it is slower, it will fill up.

We have, in a former chapter, briefly described the action of the sea upon its shores, and alluded to the rapid wearing away of some portions of the coast, while on others there was as rapid increase of land. This process is going on along our whole Atlantic border; but in no place, perhaps, is it exhibited in a more striking manner than on the shores of Long Island. The materials which form these extensive alluvial deposites are transported coastwise by tidal, marine currents, and by the action of the waves, in the direction of the prevailing winds and storms.

The winds which produce the greatest transport of alluvial matter on the coast of Long Island come from the northeast, bringing in a heavy sea, which sweeps the sand along in a westerly direction. In this manner, outlets of small bays are more or less obstructed by bars and shoals, formed by the currents sweeping past their mouths, and depositing the materials in the eddy formed by the meeting of the currents. Sometimes the surf throws up a sandbank so as to block up their mouths, and thus converts them into fresh-water ponds or lakes. Where the materials which form the barrier are coarse gravel and pebbles, the water filters through at ebb tide, and remains near the tide-level; but if they are fine sand, the water accumulates till it overflows the obstacle, or has a sufficient head to excavate a channel through the barrier and escape. In this manner almost every bay, inlet, and marsh on the north and south coast of Long Island have either had their outlets blocked up entirely by the materials deposited or so nearly as to leave only narrow entrances. The only exceptions are where they have been protected from the sea by the long sandy islands. In this way extensive tracts of beach, marsh, and salt meadows have been formed within a comparatively short time; and it is not uncommon to meet with persons on the island who will tell you of many acres having been deposited during their lifetime, and of seeing ships sail where now there is land, some feet above tide-water level.

Dunes or Downs.—These are low hills of loose sand, which have been piled up by the wind like drifting snow-heaps, and, like them, are frequently changing their size and position; so that, in some places, productive lands are buried by the moving materials, while in others they are uncovered by their removal. These hills are very common along the coast in the southeastern part of Massachusetts; and near Cape Cod they are 60 or 70 feet high, and of a snowy whiteness. They gradually move towards the west; and a series of these dunes, several miles long, now threaten the village and bay of Provincetown, and large quantities of beach-grass have been transplanted to their ridges for the purpose of arresting their progress. These hills of sand are also observed on the islands of Nantucket and Martha's Vineyard, and some of the Elizabeth Islands.

It is curious to observe, that every obstacle which creates an eddy current in the wind, as a rock, fence, bush, or tree, causes a deposite of sand, which often serves as a nucleus of a hillock, in the same manner as a snowbank is formed, which they resemble also in variety of outline and appearance. The sand is often thrown up three or four feet high in a few hours. On the shore of Long Island, these dunes are often from 10 to 40 feet in height, and extend several miles, often drifting over arable land, or filling up ponds of water. In this way the value of farms is often seriously affected. The only practical method of arresting them is by the cultivation of some plants which vegetate only in the most barren sands, as *beach-grass*, *Hudsonia*, &c. These, by their roots, confine the sand and prevent its drifting.

A Tabular View of the Rocks of the United States, with their most important Imbedded Minerals.

	Alluvium.	Bog ore (phosphate of iron), carbonic acid, sulphuretted hydrogen, carbonate of lime, carbonate of iron, sulphate of lime, sulphate of magnesia, sulphate of alumina and potassa (alum),* peat, marl, manganese, &c.
	Diluvium.	Native gold, native copper, barytes. The various ores of lead and iron, together with most of those found below in the tertiary.
	Tertiary.	Hydrate of iron (brown hematite, and many other varieties), manganese, gibbsite, carbonate of lime, iron pyrites, selenite, amber, &c.
Up. Second'y	*New Red Sandstone.*	Native copper, and the other varieties. Ores of iron, lead, zinc, barytes, strontia, lime, fluate of lime, calc spar, tripoli, bituminous coal, anthracite, gypsum, salt, mineral waters.
Up. Second'y	*Green sand. Cretaceous.*	Iron, gypsum, clays, copper, manganese, lime, magnesia, fossil organic remains.

* In mineral waters.

L. S.	*Coal Measures.*	A great variety of vegetable organic remains; iron ore in large quantities, &c.
Transition.	*Millstone Grit.* *Old Red Sandstone.* *Graywacke.*	Anthracite, plumbago, different ores of iron, epidote, zoisite, asbestos, copper, adularia, quartz, sulphate, fluate, and carbonate of lime.
	Transition or Mountain Limestone. *Argillaceous Slate.*	Ores of lead, zinc, copper, gold, quartz crystals, calcareous spar, &c.
Stratified Primitive Rocks.	*Primitive Limestone.*	Magnetic oxide and hydrate of iron, iron pyrites, copper, white augite, scapolite, tremolite, graphite, argentine, sphene, spinelle, magnesia, molybdena, epidote, garnet, satin and rhomb spar, actynolite, phosphate of lime, serpentine, &c.
	Quartz Rock.	Brown hematite, iron pyrites, hornblende, chalcedony, hornstone, jasper, ferruginous quartz, quartz crystals, &c.
	Mica Slate.	Calcareous spar, alum, phosphate of lime, fluate of lime, amianthus, different varieties of quartz, manganese, the ores of iron, lead, zinc, titanium, sulphur, anthracite, sappare, staurotide, garnet, epidote, zoisite, idocrase, stilbite, analcime, chabasie, schorl, hornblende, emerald, cyanite, &c.
	Talcose Slate.	Native gold, blue and green carbonate of copper, ores of iron, native magnet, manganese, arsenic, titanium, tremolite, asbestos, hornblende, actynolite, bitter spar, yenite, molybdenum, &c.
	Serpentine.	Amianthus, asbestos, actynolite, chalcedony, garnet, steatite, talc, quartz, magnetic iron, chrysoprase, &c.
	Hornblende Slate.	Red oxide, titanium, sphene, feldspar, epidote, arsenical cobalt, garnet, mica, micaceous oxide of iron, pyrites of iron, &c.
	Gneiss.	Graphite, epidote, ores of iron, molybdena, schorl, garnet, hornblende, actynolite, beryl, zircon, chrysoberyl, talc, adularia, copper, titanium, quartz, amethyst, chalcedony, feldspar, steatite, serpentine, alum, stilbite, emerald.

Unst'd. Prim. Rocks.	*Greenstone.*	Crystal, quartz, amethyst, chalcedony, carnelion, cacholong, epidote, asbestos, chabasie, chlorite, hornstone, calc spar, ores of iron and copper, zeolite, prehnite, selenite, Lincolnite, &c.
	Porphyry.	Gold, specular oxide of iron.
	Syenite.	Epidote, feldspar, amethyst, zircon, fluate of lime, quartz, lead, zinc, copper, titanium, barytes, hypersthene, arragonite, chabasie, &c.
	Granite.	Fluate of lime, phosphate of lime, calcareous spar, argentine, ores of copper, iron, lead, zinc, tin, manganese, molybdena, titanium, barytes, sulphur, quartz, amethyst, pinite, topaz, chrysoberyl, mica, feldspar, schorl, beryl, garnet, staurotide, talc, &c.

Note.—In forming the following table we have consulted all the authorities within our reach. But we acknowledge our particular obligations to the masterly reports of Prof. H. D. Rogers, of Pennsylvania, and of Messrs. Conrad, Vanuxem, and the other geologists of this state, who are in a fair way to reduce to something like order the hitherto chaotic formations of this country.

It will be seen from the opposite table that the highest strata in the State of New-York are the conglomerates which form the highest portion of the Catskill Mountains, which, according to Professor Rogers, is more than 3000 feet *below* the coal measures of Pennsylvania.

For the thickness of the rock formations of Pennsylvania, the reader can consult the table on page 242, *where the numbers correspond to those in the present table.*

* The sandstones and conglomerates of Catskill Mountains probably belong to the old red sandstone *group* of Murchison.

† Professor Conrad, in his "Report," &c., states that this group, consisting of *olive sandstone and slate*, cut through by Salmon River, together with the preceding *red sandstone group*, corresponds in geological position with the fourth group in the slate system of Wales, described by Prof. Philips. But this appears to us a mistake, as the whole of the four groups described by Philips belong to the clay slate system, and *lie below the lower silurian system,* which consists of the Llandeilo flags and limestone. This will appear from Mr. Conrad's own statement, that the black limestone and shale of Trenton Falls (*lying below*) correspond in position to the black shale enclosing beds of gray wacke, flagstone, &c., which are joined to the Llandeilo flags. We have made this formation correspond with the Wenlock limestone and slate above the Llandeilo flags.

An original Table, showing the equivalent Formations below the Coal Measures in the Rock Strata of England, and the States of New-York and Pennsylvania.

Formations of England.		Formations of New-York.	Formations of Pennsylvania.
			ANTH. COAL measures.(13) Conglomerates & shales.(12) Red shale.(11)
COAL MEASURES.		Conglomerates. Sandstone of Catskill Mountains.*	Sandstone and conglomerates.(10) Red sandstones and shales.(9)
Upper Silurian. *Ludlow Formation.*	Up. Ludlow rock.	Pyritiferous slate. Shales of superior series.	Olive-coloured slate.(8) Sandstone.(7) Blue limestone. Calcareous shale formation.(5) Sandstones and conglomerates of Kittatinny.(4) Slate of Kittatinny Valley.(3)
	Ayemestry limestone.	Gray sparry crinoideal limestone. Onondaga limestone.	
	Low. Ludlow rock.	Red Sandstone. Sandstones and shales of Salmon River.†	
Wenlock Formation.	Dudley and Wenlock limestone.	Blue limestone and shales of Trenton Falls. Sparry limerock of the Mohawk.	Limestone of Kittatinny Valley.(2)
	Wenlock shale.	Bastard limestone. Sparry limerock—(Eaton.)	
Lower Silurian. *Caradoc Formation.*	Flags. Sandstones. Limestones.	Calcareous sandstone of Mohawk Valley.	White and gray Sandstones.(1)
Llandeilo Formation.	Calcareous flags. Sandstone and schist.	Calciferous sandrock of Eaton. Graywacke and slate of Hudson River.	
Cambrian S.	Clay slate system.	Clay slate system.	Clay slate system.
Gneiss.		Gneiss.	Gneiss.
GRANITE.		GRANITE.	GRANITE.

CHAPTER XXVII.

FOSSIL GEOLOGY OF THE UNITED STATES.

Definition.—Paleontology.—Buckland's Remarks on the Study of Fossil Geology. — Tournefort's Idea of Fossils. — John Locke's do. Petrifactions.—How Produced.—Illustrations.—Organic Remains.—How Coloured.—Fossil Mammalia of the United States.—Big Bone Lick.—Mastodon.—Megatherium, &c.—Period when these Remains were Deposited.—Most remarkable Forms of Fossil Organization.—Encrinital or Crinoideal Limestone.

By a *fossil* is understood any body, or the traces of the existence of any body, whether animal or vegetable, which has been buried in the earth by natural causes. That department of geology which treats of fossil zoology and fossil botany has lately received the appellation of Paleontology, from "*palaios*," ancient, and "*ontology*," the science of beings. "The study of organic remains," says Buckland, "forms the peculiar feature and basis of modern geology, and is the main cause of the progress this science has made since the commencement of the present century. We find certain families of organic remains pervading strata of every age, under nearly the same generic forms which they present among existing organizations. Other families, both of animals and vegetables, are limited to particular formations, there being certain points where entire groups ceased to exist, and were replaced by others of a different character. The changes of genera and species are still more frequent; hence it has been well observed, that to attempt an investigation of the structure and revolutions of the earth, without applying minute attention to the evidences afforded by organic remains, would be no less absurd than to undertake to write the history of any ancient people without reference to the documents afforded by their medals and inscriptions, their monuments, and the ruins of their cities and temples. The study of zoology and botany has, therefore, become as indispensable to the progress of geology as a knowledge of mineralogy. Indeed, the mineral character of the inorganic matter of which the earth's strata are composed, presents so similar a succession of beds of sandstone, clay, and limestone, repeated irregularly, not only in different, but even in the same formations, that similarity of mineral composition is but an uncertain proof of contemporaneous origin, while the surest test of the identity of time is afforded by the correspondence of the organic remains: in fact, without these, the proofs of the lapse of such long periods as geology shows to have been occupied in the formation of the strata of the earth, would have been comparatively few and indecisive. The secrets of nature that are revealed to us by the history of fossil organic remains, form perhaps the most striking results at which we arrive from the study of geology. It must appear almost incredible to those who have not minutely attended to natural phenomena, that the microscopic examination of a mass of rude and lifeless limestone should often disclose the curious fact that large proportions of its substance have once been found parts of living bodies. It is surprising to consider that the walls of our houses are sometimes composed of little else than comminuted shells, that were once the domicil of other animals at the bottom of ancient seas or lakes. It is marvellous that mankind should have gone on for so many centuries in ignorance of the fact, which is now so fully demonstrated, that no small part of the present surface of the earth is derived from the remains of animals that constituted the population of ancient seas. Many extensive plains and massive mountains form, as it were, the great charnel-houses of preceding generations, in which the petrified exuviæ of extinct races of animals and vegetables are piled into stupendous monuments of the operations of life and death, during almost immeasurable periods of past time. "At the sight of a spectacle," says Cuvier, "so imposing, so terrible, as that of the wreck of animal life, forming almost the entire soil on which we tread, it is difficult to restrain the imagination from hazarding some conjectures as to the causes by which such great effects have been produced."

It is but recently, then, that fossil remains have particularly engaged the attention of geologists. The celebrated Tournefort, who lived in the 17th century, believed that that they were stones that grew, or vegetated from seeds. "How could the Cornu Ammonis," says he, "which is constantly in the figure of a volute, be formed without a seed containing the same structure in the small as in the larger forms? Who moulded it so artfully, and where are the moulds?" Of the same opinion was the philosopher John Locke, who states in his Elements of Natural Philosophy that "all stones are real *vegetables;* that is, grow organically from proper seeds, as well as plants." It is somewhat remarkable, that even at the present time, notwithstanding the progress made in geological and other natural sciences, not only the uninformed and illiterate, but even men of intelligence, should still hold to the same opinion, and maintain that the vegetable or animal fossil, dug deep from the bowels of the earth, is either a fortuitous production, or has grown to its present size from a seed or grain!

Animal or vegetable substances found imbedded in rocks are more or less impregnated with mineral matter, and have been called *petrifactions*, from *petros*, a stone, and *facio*, to make. The process of petrifaction consists in the infiltration of mineral matter into the pores of bone or vegetables. In some instances, the animal or vegetable matter has been almost dissolved or removed, and the mineral matter so gradually substituted, as to assume the perfect form of the internal structure either of the plant or animal.

In some modern deposites, we find that fossil shells have been scarcely altered in the course of centuries, having simply lost a part of their animal matter. In other cases the shell has disappeared, and left an impression only of its exterior, or a cast of its interior form, or a cast of the whole shell, the original matter of which has been removed. When this mould is filled with mineral matter, such as lime, silex, iron pyrites, &c., we then have an exact cast of the shell. But there is another kind of petrifaction still more wonderful, which may be compared to certain anatomical models in wax, when not only the outward forms and features, but even the nerves, bloodvessels, and other internal organs, are shown. We see this in corals, and particularly in fossil wood, where we can perceive not only the rings of animal growth, but all the minute vessels and medullary rays, the small pores of fibres, and even the spiral vessels, which can only be seen in a living plant by means of the microscope, as in the following cut, which represents a transverse slice of a fossil tree, thin enough to transmit light, and magnified 55 times.

Fig. 53.

Texture of a Tree from the Coal Strata—magnified.

In forming a correct idea of the mode of petrifaction, we must bear in mind that rock strata are very generally permeated by water charged with minute portions of calcareous, silicious, and other earths in solution; for we have already seen that water is capable of dissolving mineral substances to a considerable extent. When an animal or vegetable is left exposed to the open air, it putrefies and is decomposed into its original elements, oxygen, hydrogen, and carbon, which escape into the air or are washed away by the rain, so that all vestiges of them shortly disappear. Suppose, now, that they are buried in the earth, they will decompose, of course, more gradually; and, as fast as each particle is set free by decomposition, its place will be filled with particles of mineral matter, such as lime, or flint, or clay. In this way a cast of the interior of certain vessels may be taken, and afterward the walls of the same may decay and suffer a like transmutation. But when the whole is changed into stone, it may not form one homogeneous mass of stone or metal; for either some of the original woody or bony matter may remain mingled in certain parts, or, what is more often the case, the mineral which is deposited may be so crystallized in different parts as to reflect light differently, and thus exhibit the exact texture of the original body. For example, Prof. Goppert, of Breslau, steeped a variety of animal and vegetable substances in water, some holding silicious, others calcareous, others metallic matter in solution. He found that in the period of a few weeks, or even days, the original bodies thus immersed were mineralized to a certain extent. Thus, then, vertical slices of deal, taken from the Scotch fir, were immersed in a moderately strong solution of sulphate of iron. When they had been thoroughly soaked in the liquid for several days, they were dried and exposed to a red heat until the vegetable matter was burned up, and nothing remained but an oxide of iron, which was found to have taken the form of the deal so exactly, that even the dotted vessels so peculiar to this family of plants, and similar to those in the last cut, were distinctly visible under the microscope.

Organic remains are usually coloured by the strata in which they are imbedded; in roestone, chalk, and the upper fresh-water limestone, they approach a yellowish or brownish white; in *lias*, bituminous shale, and dark limestone, they incline to black; and the shells in bituminous shale are sometimes filled with bitumen in a fluid state. In the uppermost strata, bones and shells retain their original constituent parts very little changed, as in the fossil mammalia which we are about to describe. In the lower strata, the organic remains are more or less completely impregnated with mineral matter. The outer crust or shell of many chalk fossils is calcareous, and the internal part filled with flint. In some cases we find an external cast formed in the cavity of a crustaceous animal, and the external covering has disappeared; in other instances the crust or shell of the animal has formed a mould in the stone, into which mineral matter has been subsequently infiltered, and thus made an external cast. Geologists have sometimes been deceived by mistaking the mineral nucleus formed on the interior of the shell, for that which has received its impression from the outer shell. Thus, what are called *fossil screws* are the internal cast of a fossil univalve.

It is impossible, within the limits of a work like the present, to give a complete account of the organic remains hitherto discovered in our country. We shall therefore notice only such as will be most likely to interest the general reader.

Fossil mammalia.—The extinct species of the higher orders of animals found fossil in the United States are those of the mammoth (*mastodon maxi-*

mus), two species of elephant (*elephas primigenius*), the megatherium, megalonyx (*Jeffersonii*), three species of the ox family, the fossil elk, and the walrus. Of living species found fossil there are the horse, bison, and three or four species of deer. The situations in which these have been found have been either very recent undisturbed alluvial bogs, or a slightly-disturbed marshy deposite, like Big Bone Lick, neither of them covered by the general diluvium; thirdly, boggy beds containing lignite referrible to an ancient alluvium, covered by diluvial sand and gravel; and, lastly, the floors of caves, buried to a very small depth with earth not described.

The largest collections of bone-remains occur in boggy grounds called licks, affording salt, in quest of which the herbivorous animals, wild and domestic, enter the marshy spot and are sometimes mired. The most noted of these spots is Big Bone Lick, in Kentucky. occupying the bottom of a boggy valley, kept wet by a number of salt-springs, which rise over a surface of several acres. The spot is thus described by Mr. Cooper: "The substratum of the country is a fossiliferous limestone. At the lick the valley is filled up, to the depth of not less than 30 feet, with unconsolidated beds of earth of various kinds. The uppermost of these is a light yellow clay, which, apparently, is no more than the soil brought down from the high grounds by rains and land-floods. In this yellow earth are found along the water-courses, at various depths, the bones of buffaloes and other modern animals, many broken, but often quite entire. Beneath this is another thinner layer of a different soil, bearing the appearance of having been formerly the bottom of a marsh. It is more gravelly, darker coloured, softer, and contains remains of reedy plants, smaller than the cane so abundant in some parts of Kentucky, with fresh-water mollusca. In this layer, and sometimes partially imbedded in a stratum of blue clay, very compact and tenacious, are deposited the bones of extinct species." Mr. Cooper estimates, from the number of teeth and other bones removed from Big Bone Lick, that it would have required more than 100 mammoth and 20 elephants to have furnished the specimens already carried off. When the country was first discovered, many of these bones either lay on the ground, or very near it under the surface. We may form some idea of the size of the mammoth from some remains lately discovered in Jackson county, Ohio. Of these the tusk was nearly eleven feet long, and weighed 180 pounds. One of the teeth weighed 8 1-4 pounds. These bones were dug from the bank of a creek, near the water, where they were found under a mass of stratified sands and clays 15 to 18 feet in thickness.

One of the finest specimens of fossil mammoth in this country was obtained from a soft bog or meadow near Long Branch, in New-Jersey. The proprietor of the farm, walking over a reclaimed marsh, observed something projecting through the turf, which he struck with his foot, and found to be a grinder tooth. Two other teeth, some pieces of the scull, the spine, the humerus, and other bones, were afterward found. The soil around was a soft, dark peat, full of vegetable fibres. Though the scull and many other bones had been removed before Messrs. Cooper, De Kay, and Van Rensselaer examined the spot, they were able to find the vertebral column with all the joints, the ribs articulated to them, resting in their natural position, about eight or ten inches below the surface. The scapulæ both rested upon the heads of the humeri, and these, as in life, in a vertical position upon the bones of the forearm. The right forearm inclined a little backward, and the foot immediately below was a little in advance of the other, in the attitude of walking. Ten inches below the surface was the sacrum, with the pelvis united, though decayed. The femora were close by, but lay in a position nearly horizontal, the right less than the left, and both at right angles with the spine. Both tibiæ, each with its fibula, stood nearly erect in their natural place beneath the femora, and below them were the bones of the hinder feet in their places; no caudal vertebræ were seen. The marsh had been drained for three years, and the surface had, in consequence, been lowered about two feet, producing, probably, the dislocated attitude of the thigh bones. Beneath the peaty bed a sandy stratum was seen, and all the feet were noticed to be standing upon the top of this floor of the bog.

The magnificent skeleton of the mastodon* in Peale's Museum, Philadelphia, was found near the Walkill, west of the Hudson River. Fossil remains of this animal have also been discovered in Rockland county (New-York), and in all the Western States, in some instances uncovered by any diluvial deposites.

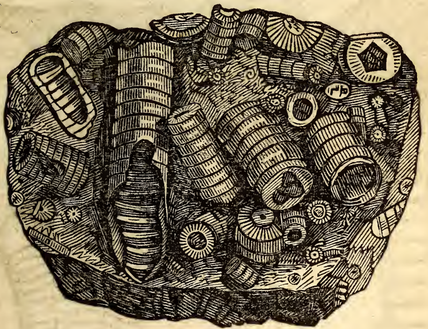
The bones of the megatherium, which is described at great length, and figured in Buckland's Geology, an animal larger than the rhinoceros, and resembling the sloth, have been found in a recent marsh on Skidaway Island (Georgia), and those of the megalonyx at the Big Bone Lick, and also in White Cave, Kentucky.

As to the period when these animals ceased to exist, there is much uncertainty. While some geologists have attributed their destruction to that catastrophe which strewed this continent with bowlders and gravel, others have supposed that they have disappeared since the flood, as their remains are often discovered in the bogs and marshes, un-

* This skeleton measures eighteen feet in length and eleven feet five inches in height. The tusks are ten feet seven inches long. It seems to have been provided with a trunk, and in its food and manner of living to have resembled the elephant.

covered by diluvium. The fact, however, that their remains are so frequently met with in the neighbourhood of salt licks, and are in such a state of preservation, would seem to indicate that they perished at a later period than the general deluge. There still, however, remains the objection, that some specimens have been discovered which were covered to a considerable depth by diluvium. The reader may balance the difficulties, and choose between them.

The State of New-York abounds with a species of limestone which has been called *encrinital*, from its containing numerous fossil encrinites, or, rather, made up of comminuted fragments of these fossil remains; very beautiful specimens of it are obtained near Hudson, and in the Helderbergh Mountains near Albany; also at Onondaga quarries, Syracuse, &c. It is sometimes, called "bird's-eye marble," and is used for ornamental purposes, as it is full of distinct annular marks of crinoidal vertebræ.



Encrinital Marble of Derbyshire, showing portions of stems of encrinites, lying in relief on a block of limestone.

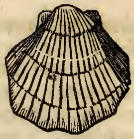
Fig. 1.

Echinus.

Fig. 2.

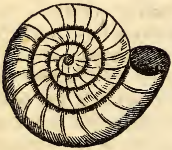
Fusus.

Fig 3.



Pecten.

Fig. 4.



Ammonite.

Fig. 5.

Belemite.

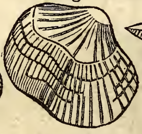
Fig. 6.

Gryphite.

Fig. 7.

Terebratula.

Fig. 8.



Producta.

Fig. 9.

Spirifer.

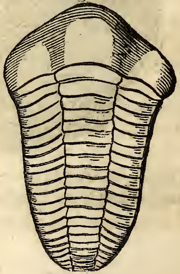
Fig. 10.

Encrinite.

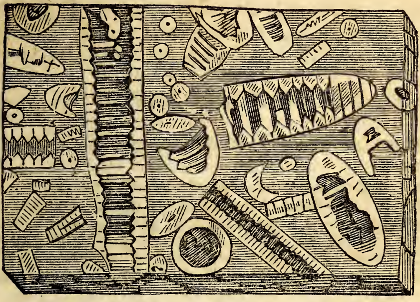
Fig. 11.

Orthoceratite.

Fig. 12.



Trilobite.



A portion of the same Marble polished.

This marble is extensively employed in England for sideboards, tables, and ornaments. What are called the *pulley*, or *screw stones*, are merely the sharp impressions of encrinital stems, forming solid cylinders, marked with annular risings and depressions. The transition limestone (and the slate formation in England) are the grand repository of these remains, upward of 50 species, belonging to 25 genera, having been collected from these ancient deposites. They are almost unknown in the upper secondary and tertiary formations; a fact which, in the opinion of geologists, indicates some remarkable change in the physical condition of the waters during these later periods, inimical to the great development of the crinoidea, which existed in the oceans of the transition era

CHAPTER XXVIII.

MINERAL RESOURCES OF THE UNITED STATES.

General Remarks.—Coal.—Rhode Island Coal-fields.—Massachusetts Coal-fields.—Mansfield.—Anthracite Coal-fields of Pennsylvania.—Amount Produced and Consumed since the Mines first opened.—Bituminous Coal-fields of Pennsylvania.—Coal-fields of Maryland—Of Virginia—Of Ohio—Kentucky—Tennessee.—Other Coal Measures of the United States.

The mineral resources of the United States but just begin to be appreciated. Hitherto we have been contented to cultivate the soil, and seek our iron, and coal, and copper, and lead, and other mineral substances, from foreign countries; but the time has at length arrived when the increasing wants of our rapidly multiplying population compel us to look for these materials nearer home. We shall endeavour, then, to give, in as short a compass as possible, an account of these resources, and, by statistical facts, show with what astonishing rapidity they are being developed.

Coal.

The coal strata have been observed as far north on this continent as human discovery has yet penetrated. At Melville Island, in latitude 75°, where the summer lasts but a few weeks, Captain Parry found in the coal formation an abundance of impressions and casts of plants which bore a tropical aspect; and in Spitzbergen, which is still nearer the North Pole, there is also an extensive coal deposite with the same remains of fossil vegetables.

As we come down the coast, the first coal-beds which we come to that are worked to any extent are those of Nova Scotia. These afford a bituminous coal of good quality, and are situated in the regular coal measures. The quantity, of course, is very great, if not inexhaustible.

Rhode Island Coal-fields.—These, though not extensive, are still worthy of notice. Those which have been explored are situated chiefly in Portsmouth, near the northern extremity of the state, and are contained in graywacke slate, and, consequently, are not in the regular measures. They began to be worked about the beginning of the present century, when the bed wrought was fourteen feet wide. Six of these beds have been wrought, and more than thirty are said to exist in the vicinity. In 1820, fifteen men only were employed, who raised from ten to twenty chaldrons of coal per day, besides keeping the mine free from water. The bed is not horizontal, but forms an angle of about seventy-five degrees. In the year 1827, twenty men and five boys raised 2200 tons of coal, and an equal quantity of *slack*, which is very small coal and dust, and the coal sold at the mine for four dollars and fifty cents per ton, which was used for burning lime and bricks. Professor Hitchcock considers that the slate in which the coal occurs is closely allied to primary rocks, because it contains asbestos.

Massachusetts Coal-fields.—We have already alluded to the anthracite coal of Worcester, which occurs in mica slate. This is about seven feet thick; but as it has been explored but a few feet, and the operations are now suspended, we shall pass it by without farther remark.

Mansfield.—In the year 1835, explorations were commenced by the Massachusetts Mining Company, in the town of Mansfield, where a shaft was sunk in graywacke, and at a depth of 25 feet struck a bed of coal five feet thick, and another one foot thick, separated from the first by 10 inches of rock. Previous to October, 1838, about 1500 tons had been raised, worth 6000 dollars, at an expense of 15,000 dollars, and the proprietors were prosecuting the work with strong confidence in a successful result. The coal is a very pure anthracite, containing from 94 to 98 per cent. of carbon. The graywacke formation in which the Mansfield coal occurs, embraces a large part of Bristol and part of Plymouth counties, as well as a part of Rhode Island. All this space is considered by some geologists as a coal-field, and, indeed, for a distance of 30 miles on its northern side, coal has been found in many places. In Foxborough, two miles from Mansfield, coal has also been found, but not in very large quantity. Small quantities of bituminous coal have been found in the new red sandstone near West Springfield, where there is an upward bend in the rock, which Prof. Hitchcock imputes to the protrusion of a basaltic dike from below.*

Anthracite Coal-fields of Pennsylvania.—No part of the world can boast of such inexhaustible beds of anthracite as the State of Pennsylvania. To use the language of Prof. Rogers: "Embracing a territory where the upper coal-bearing rocks of the great ancient secondary basis of the Continent terminate towards the east and north, the revolutions which have stripped other states of their treasures have left us in possession of some of the largest and most richly-supplied coal-fields of which any country can boast. When we regard their immense extent, comprising either the whole or a part of the area of 30 counties out of the 54 in the state, and the wide range and great thickness of many of the coal-seams; and when we contemplate the amazing variety in the character of the mineral itself, showing every known gradation from cannel coal to anthra-

* Hitchcock's Report of a re-examination of the Economical Geology of Massachusetts.

cite, fitting it thus for every possible adaptation in the arts or as a fuel, and then turn our attention to the geological and topographical structure of the regions, affording a ready access to their most secluded districts, we behold such a prodigality of happy circumstances as may well inspire exultation. It is estimated that the anthracite coal conveyed to market from our mines in the course of the last year (1837) has nearly amounted to 900,000 tons; yet this large quantity sinks into insignificance when we look at what the coal trade even in the next 10 years is destined to become. If we turn to the southern anthracite basin, the present seat of the most extensive mining operations in the state, we behold a mass of coal measuring nearly 60 miles in length and two in average breadth, having in the middle an aggregate thickness of good and available coal exceeding probably 100 feet! When we consider that from this basin and its branches above 730,000 tons have been sent to market in the course of the past year from six districts only, and when we reflect that nearly all this coal has been taken from the strata above the water-level, below which hundreds, nay, thousands of feet of coal, following the dip of the same, lie still untouched, we are made aware of the enormous amount of undeveloped resources in this coal region alone."

The anthracite coal-fields of Pennsylvania lie chiefly to the northeast of the Susquehanna River. If we trace a parallelogram, one line following the Kittatinny or Blue Mountain from the Water Gap of the river Lehigh to the Susquehanna; another from that mountain up that last river to its north branch; and a third along the north branch and its tributary the Lackawanna, until we reach a point almost due north of the point we started from, we shall then enclose nearly all the genuine anthracite seams hitherto discovered in Pennsylvania.

The most southeastern range of coal-seams may be traced parallel to the Kittatinny, nearly the whole way from the Susquehanna to the Lehigh, more than 60 miles. Near the middle of this line, which is chiefly along a valley embraced by the Sharp and Broad Mountains, about 65 seams have been counted, one half of which, at least, are productive, and those wrought will average five feet in thickness; while many are much thicker, some having a thickness of 24 feet. These seams, cropping to the surface under a mean dip of about 30 degrees, thus present a front of 200 or 300 feet of coal above the level of the valleys, from which they are entered by drifts or levels carried in from the ends of these ridges. Near the northeast end of this coal-field the seams are greatly reduced in number; but one of them, that known as the Summit Mine of the Lehigh Company, measures in thickness nearly 60 feet of solid coal.

We have not space to enter upon a description of all the coal-fields of this magnificent state. We may, however, briefly notice that which lies northwest of the Broad Mountain. Here are immense beds of coal, lying nearly horizontal, and with a thickness throughout of between 20 and 30 feet. The extreme northeastern coal-field of this region, or that lying along the valley of the north branch of the Susquehanna River, from 10 miles below Wilkesbarre to Carbondale on the Lackawanna, occurs under sufficiently simple features to enable us to estimate, with some degree of precision, the probable amount of the coal in it. This field is about 40 miles in length, with an average width of more than two miles, and the coal ranges in at least six seams continuously throughout the whole of this valley. Computing the solid matter accessible in only the two thickest of these, one of which is 24 feet, and the other six feet thick, and making due allowance for loss and waste in mining, we find that the coal-field in question can be made to furnish at least 12,000,000 tons of excellent fuel. When we consider that this is the most circumscribed of at least three distinct ranges of coal which make up the anthracite region of Pennsylvania, and that it is disproportionably smaller than the other coal-fields, we cannot fail to be impressed with amazement at the stupendous scale in which these formations present themselves.

The principal anthracite coal-fields of Pennsylvania, then, are three in number, averaging 65 miles in length and three in width. The first, or southern, or Schuylkill field, includes the Lehigh, Little Schuylkill, Schuylkill, Swatara, and Dauphin districts. The second comprises the Beaver Meadow, Shamokin, and Mahonoy districts. The third, or northern, includes the Lackawanna and Wilkesbarre, or Susquehanna districts. Each of these fields forms a long elliptical basin, with a well-defined border of red shale, and surrounded by a barrier of long and sharp mountain ridges. Two of these fields, the first and the second, run side by side, ranging a little north of east; the remaining one is somewhat apart from them, and has a more northerly direction.*

" Of the above-mentioned districts, the most important at the present time are the Schuylkill, Lehigh, Beaver Meadow, and Lackawanna. The Shamokin District is just opening, and will soon take a station among the first in the quality of its coal and extent of its products. The first field is remarkable from its containing *red-ash* coal, which is supposed to exist in none of the others to any extent. This coal is easily ignited, burns freely, and its residuum is more ponderous than that of the *white-ash*. It occupies nearly two thirds of this field. The white-ash produces a more intense heat, and leaves less residuum than the red-ash. It is free from

* Packer's Report to the Legislature of Pennsylvania, on the Coal Trade.

what are called *clinkers*, which a white heat produces in all the red-ash coals. On these accounts it is better suited for stoves and for manufacturing purposes. This is the product of the northern portion of the first or Schuylkill, as well as of the other two fields.

"The consumption of anthracite coal is rapidly increasing. It is superseding all other kinds of fuel in a considerable part of this country, for almost every purpose. It is now very generally used for domestic purposes upon the seaboard. In stationary steam-engines it is now a common fuel, and in locomotives it is daily becoming more general. During the last year it has been effectually introduced into steamboats. It is the common fuel in the coal regions for blacksmiths' forges, in preference to any other; and it has lately been introduced with success in the manufacture of iron; in Wales on a large scale, in this country on a scale sufficient to prove its economy. It may be fair to put the saving in the use of anthracite coal instead of wood as high as 50 per cent.

"The progressive consumption of anthracite coal, for the first 15 years after its introduction into use, was quite extraordinary, amounting to about 33 per cent. per annum. For the last three years the increase has been only about 16 per cent. per annum. About 830,000 tons were consumed in 1838. As our forests, too, disappear, and as the demand for timber for building purposes increases, the consumption of coal must also increase; and the period is fast approaching when its importance to us may not be less than is that of the collieries* of England to her."

* Prof. H. Vethake. Dictionary of Commerce, No. III.

Quantities of Anthracite shipped from the Mines, and a General Statement of the whole Anthracite Coal Business of Pennsylvania, since the commencement of the Coal Operations.

	Quantities of Anthracite shipped from the Mines.						General Statement.				
	Lehigh.	Schuylkill.	Lackawanna.	Pine Grove.	Shamokin.	Total.	Total receipts at tide-water.	On hand at tide-water, April 1. Surplus over consumpt'n.	On hand and brought down during the year.	Consumed of all kinds in year ending April 15, 1839.	Annual increase of consumption.
Years.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
1820	365					365	365		365	365	
1821	1073					1073	1073		1073	1073	708
1822	2240					2240	2240		2240	2240	1167
1823	5823					5823	5823		5823	5823	3583
1824	9541					9541	9541		9541	9541	3718
1825	28,393	6500				34,893	34,893		34,893	34,893	25,352
1826	31,280	16,767				48,047	48,047		48,047	43,047	8154
1827	32,070	31,360				63,430	63,430	5000	68,430	60,440	17,383
1828	30,232	47,284				77,516	77,516	8000	85,516	73,516	13,086
1829	25,110	79,973	7000			112,083	112,083	12,000	124,083	106,083	32,567
1830	42,790	89,984	43,000			175,774	175,774	18,000	193,774	133,774	27,691
1831	41,085	81,854	54,000			176,939	176,939	60,000	236,939	236,939	103,165
1832	80,000	209,271	84,600			373,871	373,871		373,871	313,871	76,932
1833	123,000	250,588	112,000	2381		487,971	487,971	60,000	547,971	427,971	114,100
1834	106,000	224,242	47,700	2450		380,646	380,636	120,000	500,636	420,820	2849*
1835	131,250	334,872	90,660	5226		562,008	562,008	79,816	641,824	641,824	221,004
1836	146,502	432,045	106,270	11,709		696,525	696,525		696,525	646,525	4701
1837	223,902	523,152	115,387	12,098		874,539	874,539	50,000	924,539	724,539	78,014
†1838	212,831	433,875	76,321	13,809	3746	727,582	727,582	200,000	927,582	827,582	103,043

* Decrease. † Dictionary of Commerce, p. 366.

THE BITUMINOUS COAL-FIELDS OF PENNSYLVANIA.

Great and valuable as are the anthracite deposites of Pennsylvania, her bituminous coal-region is still more extensive and inexhaustible. We have already stated that the great secondary deposite, which extends from the Hudson to the Mississippi, and probably to the Rocky Mountains, is in Pennsylvania limited by the Alleghany Mountains, which appear to form the barrier or dividing line between the anthracite and bituminous coal-beds, or between the secondary and transition formations. The union or junction of these formations is distinctly marked in the end of the mountain where the west branch of the Susquehanna breaks through it, above Bald Eagle, the latter resting against the former, and forming the basin in which the bituminous coal, in regular and successive strata, is deposited.

This coal-field, therefore, is confined to the west side of the Alleghany, and is supposed to extend to the centre of the mountain. In the southeast corner of Somerset county, and in the western parts of Bedford and Huntingdon counties, this coal deposite would appear to extend to the southeast of what is there called the Alleghany, and occurs in great abundance on Will's Creek, Jennings Creek, &c., emptying into the Potomac. The bituminous coal-beds vary from one foot to 12 in thickness, but rarely exceed six feet. They lie in nearly horizontal strata, with about sufficient dip to free the mines from water; some hills containing three and four beds, with alternate layers of earth and strata, resting between a firm, smooth slate roof and floor, as shown in the sections above given. Faults are seldom met with, as is the case in the anthracite strata, which goes to prove that all this vast extent of secondary rocks was once the bottom of a great lake or sea, which has been drained by the waters of the Mississippi, the St. Lawrence, the Susquehanna, and the Hudson. It is a curious fact, that near the northern termination of this coal-field in Potter county (Penn.), the head-waters of the Alleghany, the Susquehanna, and the Genessee rivers, flowing into the Gulf of Mexico, the Chesapeake and the St. Lawrence take their rise in an area or space of about five miles.

This coal-field, then, which is bounded on the south by the Alleghany Mountains, extends into the State of Virginia and westward, so that bituminous coal abounds to a greater or less extent in all the western counties of Pennsylvania, with the exception of Erie, in which it has not been discovered. The counties of Bradford, Lycoming, Tioga, Potter, M'Kean, Warren, Crawford, Bedford, Huntingdon, and Centre, lie partly in and partly out of the coal-field. The counties of Alleghany, Armstrong, Beaver, Butler, Cambria, Clearfield, Fayette, Greene, Indiana, Jefferson, Mercer, Somerset, Venango, Washington, and Westmoreland, are wholly within its range, and embrace together an area of 21,000 *square miles*, or 13,440,000 acres, while the anthracite coal districts have been computed to contain but 624,000 acres.*

Bituminous coal has been used for fuel and manufacturing purposes in the western part of Pennsylvania since the first settlement of the country. It is mined, to a greater or less extent, in all the counties above named, at the rate of one cent and two cents per bushel, and is thus brought within the means of all, and, literally, to every man's door. Abounding throughout all this vast extent of territory, and fitted and used for almost any purpose requiring heat, it is impossible to form anything like a correct estimate of the quantity consumed yearly and sent to market. Its great abundance and cheapness have, indeed, given birth to the vast

* Packer's Report to the Senate of Pennsylvania, March 4th, 1834.

and widely-extended manufacturing establishments of the West. Without coal they could not exist. It thus constitutes the lifespring of western Pennsylvania, and the pedestal of her great manufacturing emporium, Pittsburg. This city alone and its environs, in 1835, contained 120 steam-engines for the various manufactures of iron, steel, glass, cotton, salt, brass, white-lead, flour, oil, leather, &c. These engines consume annually nearly 3,000,000 bushels of coal.

The coal consumed for every purpose in and about Pittsburg has been estimated at 7,665,000 bushels, or 255,500 tons. At four cents a bushel, the price now paid in Pittsburg, it would amount to 306,512 dollars. Besides this, great quantities are shipped to Cincinnati, New-Orleans, and the intermediate places, where it is sold for from 5 to 10 dollars a ton. Large quantities of it are also consumed in the western counties of Pennsylvania in the manufacture of salt, as there are more than 100 salt-manufacturing establishments in that region, and many others going into operation, which produce annually more than 1,000,000 bushels of salt, and consume 5,000,000 bushels of coal. The total amount of anthracite and bituminous coal at present derived from the coal-beds of Pennsylvania cannot fall much short of 2,000,000* tons annually, being about one twelfth as much as the total annual product of all the coal-fields of Great Britain, nearly half as great as that of all the rest of Europe, and about equal to that of France.

These facts, elucidating the immense mineral wealth of the great and justly called *keystone* state, open to the imagination a long vista of power and

* The *coking process* is now understood in Pennsylvania, and it is found that the bituminous coal is quite as susceptible of this operation, and produces as good coke as that of Great Britain. Indeed, it is now used to considerable extent in some of her iron manufactures

greatness, which the utmost stretch of the imagination is hardly able to equal.*

COAL-FIELDS OF MARYLAND.

These are bituminous, and, so far as discovered, two in number, viz., the Cumberland Field, extending from Will's Creek to the head branch of the Potomac, being about 60 miles in length by from five to seven in width, covering an area of 400 sq. miles; the coal existing in beds of from three to fifteen feet thick, of an excellent quality, burning easily, with a bright and durable flame, caking, and leaving little residue. The other, called the Youghiogeny Field, lies west of the Alleghany Ridge, is of unknown extent, and has beds of coal 20 feet in thickness.

The Cumberland Coal-field, sometimes called the Frostburgh Coal-field, in Alleghany county (Md.), is worthy of particular notice, on account of the remarkable character of the coal, it being intermediate between anthracite and the usual variety of bituminous coal. The boundaries are the Savage Mountain on the west, and Dan Mountain on the east, these ranges being from 1200 to 1500 feet above the general surface of the lower parts of the intermediate country, which is composed of numerous high hills and deep valleys, often narrow and abrupt. Professor Ducatel† estimates the elevation of the coal-field above the sea to be about 1850 feet, though it is generally estimated at 1500 feet; and 1000 feet above the village of Cumberland, 11 miles distant.

The shape and structure of this coal-field has been compared to that of a canoe, or, rather, of several canoes placed one within the other, representing the successive strata of coal, shale or slate, sandstone, iron ore, and limestone, of which this trough is composed. The coal, shale, and sandstone are

* Dr. Hildreth.

† Report, &c., 1836.

to be seen in almost every natural or artificial section of the country; while the iron ore and the limestone occasionally occur, and often form regular strata. There are in the Frostburgh region six or eight accessible coal-beds, which vary in thickness from one to twelve feet. The *great bed* averages at least ten feet of excellent workable coal, and the minor beds are from three to eight feet thick. These beds are situated most favourably also for draining, as the water runs down into the valleys from the adits, and is thus carried off. They are also perfectly inexhaustible, and, being situated near the Chesapeake and Ohio Canal, to be completed the ensuing year, with which a railroad will communicate directly from the mines, afford the most flattering prospects of wealth to the enterprising companies now engaged in working them.

Character of the Cumberland Coal.—This is probably the most valuable coal, not only for manufacturing, but also for domestic purposes, hitherto discovered in this country. Analyses by several distinguished chemists prove that it contains no sulphur, which is injurious in the manufacture of iron, and that it presents, on the average, from 78 to 80 per cent. of carbon, with 15 to 20 per cent. of bituminous and earthy matter, the latter being about five per cent., with only a trace of iron.

It has been found very difficult, and, indeed, impossible, to employ some coal for the smelting of iron, as it imparts to it a degree of brittleness, as well as injures its malleability; but no such effects attend the use of Cumberland coal. It is, accordingly, a favourite fuel in the public armory at Harper's Ferry. It also affords an excellent coke, which affords a very intense heat. But, even without coking, the large amount of carbon which it contains adapts it extremely well to the production of an intense heat; while the bitumen, although in small proportion compared with the common bituminous coals, is still sufficient to produce a ready combustion, which is very enduring on account of the large quantity of carbon. In general, this coal burns with little or no odour, and exhales so little smoke or fume, that it does not line the chimney with any combustible matter; the chimney, therefore, needs no cleansing; no exhalation is emitted to soil the furniture of a room; and it is even asserted, that any white substance held in the current of a chimney contracts no fuliginous tint from the burning of this coal. In a grate it kindles easily, and burns with a degree of vivacity intermediate between that of bituminous coal and anthracite, while the heat and its endurance are in the same relation; it lasts through the night, affording a mass of fire in the morning which is easily revived by adding more coal.

It possesses the usual slaty structure of the bituminous coals, is intensely black and brilliant, and is preferred by those who have used it both to the anthracite and the common bituminous coals. Professor Silliman, from whose late able Report to the New-York and Maryland Coal and Iron Company we have obtained these facts, remarks, that the discovery of this coal "is a very important acquisition to the nation. It has for ages reposed, almost unknown, in the bosom of its native mountains, and would still, as regards the public, have remained a sealed treasure, had not the great canal opened a channel, by means of which it will soon be brought into the market, and placed in competition with the coal of other regions."* The above description will also apply to the coal found in the Savage Mountain, on what is called the Howell Estate, in the same vicinity; which embraces three distinct beds of from three to twelve feet thick, also associated

* This coal-field rests upon old red sandstone, and this upon transition limestone, full of encrinites and trilobites.

with beds of iron ore, which yield from 34 to 63 1-2 per cent. of metallic iron.*

Our limits do not allow us to enter upon a description of the Maryland Coal-field, which lies west of the Back Bone or Alleghany Ridge; suffice it to say, that it alone would supply this country with coal for a long succession of years.

COAL-FIELDS OF VIRGINIA.

The coal-fields of Virginia are numerous and extensive, but a brief description must suffice. That which we would designate as the first coal-field, lies at the junction of the middle and tide-water section, extending from the Pamunky by Richmond to the Appomattox, a distance of about thirty-five miles, with a breadth of from one to eight miles. The coal is bituminous, in seams of enormous thickness, being sometimes thirty, forty, or even sixty feet thick, and of excellent quality. Traces of coal have also been found on both sides of the Upper Appomattox. The coal of the Richmond basin is now largely mined, and sent off in considerable quantities. Anthracite of great purity is found in the valley from the Potomac to the James River, south of which it contains a considerable portion of bitumen, but less than that of the ordinary bituminous coal. Beyond the Alleghany there are some of the most extensive and valuable deposites of bituminous coal in the United States, which derive additional value from their being associated with not less important beds of iron and rich salines. At Wheeling, on the Ohio, and for fourteen miles down the river, the bank presents an uninterrupted bed of highly bituminous coal, upward of sixteen feet thick. The Wheeling basin extends about thirty miles up and down the river in Ohio and Virginia. Another vast field stretches from about Clarksburgh, on the

* On the Baltimore and Ohio Railroad, 25 cwt. of the Howell coal performed the work of two tons of anthracite.

Monongahela, to Pittsburg, and far beyond to the northeast in Pennsylvania. In some places in this field the seams are from ten to twelve feet thick. There is also a valuable coal-field on the head waters of the north branch of the Potomac. A simple enumeration of the strata here exposed will furnish an illustration of the resources of this corner of the state, well calculated to inspire astonishment and exultation. Upon a stratum of valuable iron ore, not less than fifteen feet in thickness, there rests a bed of sandstone, upon which reposes a coal-seam three feet thick; above this another bed of sandstone, then a two feet vein of coal; next sandstone, then another coal-seam of four feet; again a stratum of sandstone, and over it a seven feet vein of coal; over this a heavy bed of iron ore, and, crowning the series, an enormous coal-seam of from fifteen to twenty feet in thickness. Thus we have five tiers of coal-seams, with an aggregate of from thirty to thirty-five feet. There are also coal-seams, associated with salt-springs, on the Little Kanawha, and springs of petroleum or rockoil occur in the same tract. On the Great Kanawha is a very rich and extensive coal-field; on the Coal, Ganley, and other rivers in this portion of the West, the beds of this mineral are frequently brought to view; and, in fact, no better general description can be presented of its extent, than that it is almost continuous with the vast beds of sandstone which spread in nearly horizontal planes over nearly the whole of this broad region.* The coals of Virginia contain from twenty-seven to thirty-eight per cent. of bituminous matter, and from seventy-five to eighty-nine per cent. of pure charcoal or carbon. It is a remarkable fact, that nearly all the coal-beds in this country, like those of England, are associated with iron ore, as if on purpose for its reduction. With respect to the mineral treasures of

* Professor W. B. Rogers's Geological Reconnoisance.

western Virginia, Prof. Rogers remarks: "How magnificent is the picture of the resources of this region, and how exhilarating the contemplation of all the happy influences upon the enterprise, wealth, and intellectual improvement of its inhabitants, which are rapidly to follow the successive development of its inexhaustible mineral possessions. In a country where the channels of nearly all the principal rivers have been scooped out, in part, through beds of coal; where some of them are paved with the richest ores of iron; and where the very rock itself, the steril sandstone of the cliffs and mountains, is enriched at certain depths with abundant stores of salt, what more is needed to fulfil the happy destinies that await it, than to awaken enterprise to a due appreciation of the golden promises it holds out, and to direct industrious and active research to the thorough investigation of the character, position, and uses of the treasures it contains?"*

COAL-FIELDS OF OHIO.

Were we to state that the whole of the south and eastern part of the State of Ohio was one magnificent coal-field, we believe we should not vary far from the truth; but, as explorations have been made as yet, comparatively, in few places, we must limit our brief description to such deposites as have been exposed to view, or penetrated in borings for salt. "The immense beds of bituminous coal," says Dr. Hildreth, "found in the Valley of the Ohio, fill the mind with wonder and surprise as it reflects on the vast forests of arborescent plants required in their formation. Age after age, successive growths of plants springing up in the same region were en-

* Besides coal and iron, Virginia contains gold, copper, lead, salt, limestone, marls, gypsum, magnesian, copperas, and alum earths; thermal, chalybeate, and sulphuretted springs; excellent marbles, granites, soapstones, sandstones, &c.

tombed beneath thick strata of shale and sandstone, until the whole series had accumulated to a depth of more than a thousand feet; while beneath the whole lay the bed of an ancient ocean, floored with fossil salt. Indications of coal are found at intervals across the great valley from the Alleghany to the Rocky Mountains. It is found near the surface in Kentucky, Ohio, Indiana, Illinois, and Missouri, and, without doubt, may be found beneath the extensive tertiary deposites which form the substratum of the great prairies in the central and northern parts of the Western states. As low down as New-Madrid, on the Mississippi, coal was thrown up from beneath the bed of the river by the great earthquakes of 1812; a sufficient proof of its continuation in the most depressed part of the great valley." "Where not removed by degradation or buried under other strata, there seem to have been eight distinct deposites of coal throughout the main coal-region of Ohio, some of which were covered with marine deposites; in others the deposite was made in fresh water, as is demonstrated by the character of the fossil shells found in the rocks, both over and under the coal."

Coal-field of the Muskingum.—The Muskingum River empties into the Ohio on the west, after traversing Muskingum, Morgan, and Washington counties, through a beautiful valley nearly 200 miles in length, by from 50 to 100 or more in breadth. All the northeast part of the valley, and the hilly sandstone region south and east between the Muskingum and the Ohio, belong to the carboniferous group and the coal measures; and nearly all the streams that flow into the Ohio, in some part of their course, pass over deposites of bituminous coal; while the streams which run north into Lake Erie pass over calcareous rocks, and lie without the margin of that great coal-basin, through the most depending part of which the Ohio takes its course.

The geological structure of this coal-field is very similar to those already described. Some parts of the valley belong to the tertiary, some to the carboniferous, and some to the red sandstone group. The remains of fossil plants are very numerous and beautiful, and the beds of red marl are of immense thickness, often as much as 40 feet, which, on exposure to the air and frosts, decompose into a red clay highly charged with iron, and disclosing nodules of red oxide of iron in considerable quantities, and shells of the genus *unio*, which shows that the deposites were made in fresh water. In boring for salt water six miles above the mouth of the Muskingum in 1834, after passing through 40 feet of clay, they came upon a softer clay, mixed with sand and small fragments of wood, leaves, and seeds of monocotyledinous plants; and under this a bed of woody materials, composed of the fragments of trunks and branches of trees, grapevines, seeds, and leaves. Under this was a deposite of 10 feet of fine sand mixed with clay, precisely such as we find in the beds of our ponds, and mixed with numerous fresh-water shells. The reader may learn the nature of the strata of the coal-fields of Ohio by recurring to the sections given in our chapter on the coal measures. An excellent species of coal, similar to that of the Cumberland beds, and called by some *Cannel coal*, has been discovered on Will's Creek, in Guernsey county, of which an account is published in the 18th volume of Silliman's Journal.

Hocking Valley Coal-field.—The Hocking River is about 80 miles long, and, with its tributary streams, drains a valley about 20 miles in width. The valley is generally hilly and broken, the hills rising from 200 to 300 feet high. In the centre of this valley bituminous coal is found in abundance, and with its associated minerals, iron and salt, will soon be extensive and lucrative articles of commerce. It is found in three principal beds, pursuing the same order as in many other portions of the great basin. One is near the base of the hills, and in the beds of creeks, which is usually the best coal. Another is found about 50 feet above, and a third near the tops of the hills. A stratum found in one hill is seen in another, at the distance of a quarter or half a mile, across a valley or ravine at the same elevation, the intermediate rocks having evidently been removed in the course of ages. The first coal-bed averages about four, and the latter from six to ten feet thick, and is of an excellent quality. Another bed exists still above this. Thus, in sinking a salt-well on Sunday Creek, four miles above the mouth, a stratum of coal was passed nine feet thick at a depth of 80 feet. Near the mouth of the creek, at another well, it was passed at the depth of 94 feet, and was six feet thick; and at Athens, four miles below, a bed of coal was passed, at the depth of 185 feet, six feet thick; and half a mile farther, the same bed is penetrated at 300 feet below the surface, where it is eight feet thick, showing the coal-bed dips 220 feet or three degrees in less than five miles, which brings it cropping out on the surface six miles up the stream.

Coal-fields of Jackson, Scioto, and Lawrence counties.—In these counties, which occupy the southeast corner of the state, are also three workable beds of coal, doubtless equivalent to those of the Hocking Valley. The western outcrop of the lowest seam may be indicated by a line drawn from the Ohio River, near the Franklin Furnace in Scioto county, northward to Richland in Jackson county; but, as this outcrop is irregular, coal may be found west of this line on *high elevations*, and be deficient in those *east* of it. This coal contains distinct traces of vegetable fibre, burns with a brilliant yellowish flame, and, being free from sulphuret of iron, is highly esteemed for fuel and smith's purposes, and may doubtless be used to advantage in the smelting of iron. This coal has been worked in various places, and is now delivered at Chilicothe at 16 cents a bushel, of which many thousand bushels are annually consumed.

The thickness of these three beds of coal ranges from 10 to 17 feet. "The whole amount of coal," says Mr. Briggs, "between the Ohio River and the Hocking Valley, may be safely estimated as sufficient to form an entire stratum 50 miles in length, five miles in width, and nine feet in thickness. This amount of coal will yield about 9,000,000 of tons per square mile. This estimate includes but a very small part of the coal which can be obtained from the beds heretofore described; for, after disappearing beneath the water-courses, they doubtless continue eastward towards the Ohio River, sinking deeper and deeper beneath the surface, so that they can be reached only by shafts near the Ohio at the depth of some hundred feet. The method of obtaining coal by sinking shafts has not yet been practised in this country to any considerable extent, but will ultimately be in Ohio, when the consumption of fossil coal shall have created a sufficient demand for the article. Shafts have been sunk with success, under the direction of practical geologists in Great Britain, to the depth of 1200 to 1500 feet. Coal must undoubtedly be obtained in this way in our own country at no very remote period."*

COAL-FIELDS IN KENTUCKY.

Extensive beds of coal are found along the base of the Cumberland Mountains, stretching along 120 miles west of them, in the heads of Licking, Kentucky, Green, and Cumberland rivers. Throughout this region, embracing the sides and spurs of Cumberland Mountains, the prevailing rock is sandstone; on its western limit it changes to limestone,

* Report to the Legislature of Ohio, 1838, p. 87.

often intermixed with nodules of flint, and containing imbedded detached masses of lead ore. Salt water is found on all the head branches of the Kentucky River, but is most abundant on the south fork. Coal is sometimes seen on the borders at the limestone rocks, resting on slate, and covered with a calcareous roof. On Green River, coal is found to within 50 miles of its mouth. Salt water is also obtained at a depth of 80 feet, with an abundance of carburetted hydrogen and petroleum. About a mile from the Cumberland River, in Adair county, in boring for salt water, a bed of coal 45 feet thick was struck 30 feet below the surface, and at 150 feet beneath the coal a vein of salt water was reached, into which the auger dropped, and immense quantities of gas were discharged for a number of days. Indeed, coal and salt water may be said to abound from the heads of the Cumberland River to the heads of the Licking, occupying the whole of the northern and eastern borders of the State of Kentucky. West of this line iron ore is abundant

COAL-FIELDS OF TENNESSEE.

In Tennessee, according to Dr. Troost, the coal measures are confined exclusively to the group of the Cumberland Mountains and subordinate ridges. Commencing at the south, it first appears in Mount Sano, east of Huntsville, Alabama, where it crops out in several places. Following this subordinate ridge till we come to the main Cumberland Mountain, we find the coal cropping out in numerous places, as near Battle Creek, 10 miles from Jasper, Marion county. The coal is deposited in horizontal layers of great extent, and probably may be found everywhere in the mountains by boring. Near the northern limit of the state, the breadth of the coal formation seems to be the greatest; it comprises here part of Overton, the whole of Fentress, Campbell, and part of Claiborne counties. Besides in these, coal abounds in White, Morgan, Anderson, Roane, Warren, Bledsoe, Rhea, Hamilton, Marion, and Franklin counties. The coal is bituminous and of an excellent quality, burning freely with much smoke, and a white, bright flame, furnishing a good coke, and containing about 70 per cent. of carbon.

OTHER COAL-FIELDS OF THE UNITED STATES.

We have thus briefly described the most important coal-fields of our country which have as yet been explored; there are known to exist numerous others, which at no distant day will probably rise to an equal degree of importance. Such are those of Illinois, Alabama, Mississippi, and Indiana, some of which are already worked to a considerable extent, especially on the Wabash. We have, however, stated enough to satisfy the reader that nature has been most lavish in her distribution of this valuable mineral over the surface of our country, and in those very places, too, where it would seem to be most needed; and that no country on the globe can boast an equal amount of coal deposites with the United States of America.

CHAPTER XXIX.

MINERAL RESOURCES OF THE UNITED STATES—(Continued.)

IRON.

Iron.—Its importance in the Arts.—Iron in Maine—New-Hampshire—Salisbury (Conn.)—State of New-York—Columbia—Dutchess and Orange Counties.—The Stirling Mine.—Iron in Franklin and St. Lawrence Counties.—Iron Ores of New-Jersey—Of Pennsylvania and Ohio.—Dr. Hildreth's Report.

Iron ore is the most abundant metallic mineral in the United States; and it is found in greater or less quantity in every state of the Union. It is impossible to glance even at its most important localities; we shall, however, designate some of them, and add such considerations as naturally suggest themselves in connexion with this subject.

"Iron," says Dr. Jackson, "is one of the essential requisites in all the arts of civilized society, and is the strong arm of national prosperity. It is a knowledge of the art of working this metal that distinguishes the more powerful civilized races of mankind, and gives them the means of withstanding the encroachments of barbarians. Iron is the metal that gives us the power of subduing nature to our will. It forms the plough that tills our fields, and the sword, spear, and gun which defend them. On the one hand it is employed as culinary utensils, in which our food is prepared, and on the other it is made to hurl cannon-balls at our foes. From the plough to the penknife, it is the most universal metal employed in the arts of life. Its magnetic properties directed Columbus across the ocean and discovered this continent; the same property serves now to direct our course through the midst of pathless seas and tangled forests, while it also serves to point out the boundary of our landed estates."* It has been computed that the real amount of actual value received from iron mines is ten times as much as is obtained from those of gold and silver, and half of the whole value of the metals known and wrought in the world.

IRON ORE IN MAINE.

In the State of Maine the ores of iron are valuable and abundant; and at Woodstock, in the northern part of the state, bordering on the British Provinces, there is one of the most extensive veins of this metal ever discovered. Dr. Jackson states that it is nearly 900 feet wide, and runs through an un-

* Second Report on the Geology of Maine.

known extent of country. The ore is the compact red hematite, and yields 44 per cent. of pure metallic iron, and 50 per cent. of cast iron. By a simple calculation, it can be shown that, as a cubic foot of the ore weighs 200 lbs., if the bed were wrought to the depth of 100 feet, and 500 feet in length, it would yield 45,000,000 cubic feet of ore. A vein of magnetic iron ore exists on Marshall's Island, about three feet wide; and on the Aroostook River is a bed of red hematite iron of the best quality, 36 feet wide, and of immense and unknown length.

In New-Hampshire, Vermont, and Massachusetts, iron ore is also abundant; and in Connecticut, at Salisbury, is the most valuable kind of iron ore wrought in this country, of which more than 3000 tons of pig iron are annually manufactured. The malleable iron obtained from this region is highly valued for its toughness and softness, and is extensively employed in making anchors, musket and pistol-barrels, wire, and all kinds of hollow ware. The public armory at Springfield is supplied with this iron, and from it are made most of the large anchors for the United States' navy.

IRON ORE OF NEW-YORK.

The State of New-York also furnishes an abundance of this useful metal. In Columbia and Dutchess counties the mines are numerous and easily worked, and free from water. These beds yield annually about 20,000 tons of ore, which is worth at the spot from $1 50 to $2 50 per ton. Within 12 miles of Amenia there are 10 furnaces, which make 10,000 tons of iron per annum, and afford employment to 1000 men. There are several other furnaces in Columbia and Dutchess counties; and the aggregate value of the pig iron made at them all is estimated at $500,000 per annum. Much of this iron, especially that made from the bed in Amenia, which yields 5000 tons of ore per annum, is said to equal that from Salisbury. Much of the ore in these counties lies in a tertiary formation, under a deposite of pebbles, gravel, and loam, and frequently, as at Amenia, at the junction of talcose slate and limestone.

In Orange county there is an abundance of iron, forming beds in primitive rocks, particularly gneiss, from one to twenty feet in thickness. The most important of these are the Stirling, Long, Patterson, Mountain, Clove, Forshee, and O'Neil mines, though there are many others of great extent and value. The Stirling mine was discovered in 1750, and named after Lord Stirling, then proprietor of the soil. A furnace was erected in 1751, from which time from 500 to 2000 tons of ore, annually, have been consumed, making nearly 150,000 tons up to this time. The ore is from 10 to 20 feet thick, and makes sound and strong iron, suitable for casting cannon, for which it has been much employed. The first steel made in the State of New-York was in 1776, from the Stirling ore; and in 1810 blister steel was made from it, which was used for edge tools, and found to be equal to the best Swedish iron. The first ore ever made in the State of New-York was at Stirling Forge, in 1773. The great chain which was extended across the Hudson at that point during the revolution, was made at Stirling, in March and April, 1788, by the late Peter Townsend, Esq. It was contracted for, and its making superintended, by Timothy Pickering, Esq. The iron of this chain was made from equal parts of Stirling and Long Mine ores; the weight of each link was about 150 lbs., and the whole chain weighed 186 tons, and was made and delivered in six weeks. The first cannon made in the State of New-York were manufactured from the iron of Long Mine in 1816, and were 6, 12, 18, 24, and 32 pounders. They were all made for the government of the United States, and not one failed in the proof

In the northern part of the State of New-York, iron ore is abundantly distributed in the form of the magnetic and specular oxide, and bog iron ore; and in Jefferson county, not even a mile can be travelled over without observing frequent indications of this metal. The *magnetic oxide* occurs in beds, of from one to 500 feet in width, in granite and gneiss; the beds being parallel to the direction of the mountain ranges, and in gneiss parallel to its apparent stratification. They dip, like the rock strata, at an angle of 70 or 80 degrees. Some idea may be formed of the immense quantity of iron in this region, when we state that at Newcomb, a few miles from the Hudson River, a bed has been traced more than a mile in length and 300 feet in width; and about a mile north is another bed 500 feet wide, which extends nearly a mile, and of an unknown depth. There is also a great abundance of timber and "water-power," and other facilities for the extensive manufacture of this metal; nothing being wanted but a railroad of 40 miles to transport it to the navigable waters of the Hudson. The whole of Franklin and St. Lawrence counties may be said to be iron districts, destined at no distant period to abound in extensive iron manufacturing establishments. There is already manufactured in Essex county 1500 tons; in Clinton county, 3000 tons (all of which latter is made directly into malleable iron, and converted into hooks, bolts, nails, anchors, chain cables, &c.); in Franklin county, 600 tons; in St. Lawrence county, 2000 tons; and in Jefferson county, 450 tons of iron* annually. The value of the iron annually manufactured in the above-named counties is more than half a million of dollars annually.† When we consider the im-

* Mr. Emmons's Report to the Legislature of New-York, 1837.

† In England, in the year 1828, there was manufactured 732,000 tons of iron.

mense demand of iron for railroads and other purposes, and also the high price that bar iron commands,* it is remarkable that the attention of capitalists is not more directed to the manufacture of this important article. The value of iron and steel imported into the United States during the year 1836, was $7,717,910; and in 1835, $5,000,000. During the seven years previous to 1836, the importation of iron was seven per cent. over the seven years from 1821 to 1828. The demand for railroad iron during the next ten years will probably be greater, by far, than during the last ten.

IRON ORES OF NEW-JERSEY.

The whole of the primary region of Jersey, which we have already pointed out, abounds in iron ore, which constitutes three *lodes* or veins of vast longitudinal extent, always in the direction of the strata including them. They occur, as in the State of New-York, in the granitic gneiss rock, *ranging* and *dipping* with it. These veins are usually from six to twelve feet thick, but they have nowhere been explored at a greater depth below the surface than 212 feet. The ore is generally the magnetic oxide, containing about 67 per cent. of metallic iron. Bergen, Sussex, and Morris counties are rich in iron deposites. In 1830 there were 28 furnaces and 108 forges in the state; and the value of the iron manufactures was $1,000,000. Since then they have much increased.

IRON ORES OF PENNSYLVANIA AND OHIO.

Few regions of similar extent, in any country on the globe, possess this invaluable mineral in such quantity and variety as these two states. The lime-

* Dr. Jackson states that at Woodstock, Me., bar iron commands $120 a ton; generally in Maine, $100 per ton; and castings, $75 per ton; and, while it can be manufactured for $35 per ton, the profit may easily be calculated.

stone valleys, as those of the Kittatinny, abound in *brown iron ore*, including the two varieties, *hematite and pipe ore;* while nearly the whole series of coal measures contain an equally profuse supply of rich *argillaceous ore*. When we consider the contiguity of these two minerals, their invaluable adaptation to each other, their exhaustless abundance, how their presence is calculated to stimulate to the cultivation of the useful manufacturing arts, the industry of the people, what a glorious picture of wealth, of activity, of prosperity and happiness, does the contemplation present!

To form some idea of the value and importance of the iron business in Ohio, we present the following extract from a report of Dr. Hildreth on the manufactures of the two counties, Scioto and Lawrence, in the year 1836. "The furnaces make an average amount of 1000 tons of pig iron per year, some of them making more than this quantity, and others less. During the past season, pig iron has been worth $40 per ton at the landing, where the metal is delivered to purchasers. Producing an amount of iron worth $250,000 per year, one half of this quantity is made into castings and stoves, directly as the metal flows from the furnace, worth $60 per ton, which will add $130,000 more to the gross amount, making the sum of $650,000 as the product of these 13 furnaces. The number of furnaces is steadily on the increase, several new ones going into operation the present year; in addition to which, the bar iron manufactured at the forges will swell the present amount to a considerably larger sum. Each furnace employs, on an average, about 100 men and 50 yoke of oxen, all of which are fed from produce grown in these counties, and those lying higher up the country on the Ohio and Muskingum rivers, affording an extensive home market for large quantities of corn, oats, flour, and bacon, and already nearly as important as that of Cincinnati to many of the river counties. The furnaces on the Kentucky side of the Ohio River, in the iron ore region, are quite as numerous as those in that state, and assist in giving permanence and value to this new market. When the number of furnaces is quadrupled, as they in a short time must be, from the regularly increased demand for iron in railroads, steam-engines, &c., the value of the iron manufacture will be swelled to several millions, and the market for the productions of the soil be proportionally increased. So true is it that agriculture and manufactures are twin sisters, and go hand in hand, affording mutual benefit and assistance to each other."*

It is computed that at least 12,000 square miles in the State of Ohio are underlaid by coal, and as much by beds of iron ore. Mr. Briggs, in his report to the Legislature of Ohio for 1838, remarks, " at a very low calculation of the amount of good iron ore in the region which has this season been explored, it is equal to a solid unbroken stratum 61 miles in length, six miles in width, and three feet thick. A square mile of this layer being equivalent in round numbers to 3,000,000 cubic yards; when smelted, will yield as many tons of pig iron. This number, multiplied by the number of square miles contained in the stratum, will give 1,080,000,000 tons: which, from these counties alone, will yield annually, for 2700 years, 400,000 tons of iron; more than equal to the greatest amount made in England previous to the year 1829."

The states of Kentucky, Tennessee, Indiana, Illinois, Maryland, and Virginia, supply also inexhaustible quantities of iron ore; and in Tennessee alone there are now annually manufactured nearly 100,000 tons of iron; each furnace, of which there are now more than 30 in Middle Tennessee, producing an annual average of 1000 tons of metal per year.

* First Annual Report on the Geol. Survey of Ohio, 1838.

In 1810, the quantity of bar iron made in the United States was 29,000 tons; in 1830, 112,860 tons, and also 191,536 tons of pig iron, of the value of 13,329,760 dollars. In 1810, the total value of our iron manufactures was estimated at $14,364,526. At present it exceeds, probably, $50,000,000, as there is not only a vast increase in the amount of the articles produced, but many new branches of manufacture have been introduced within the last few years. More than half our hardware and cutlery, and a great proportion of our railroad iron, are still imported from Great Britain. Our iron manufactures consist chiefly, at present, of steam-engines, and all kinds of machinery, nails, fire-grates, and stoves, hollow ware for domestic purposes, chain cables, anchors, agricultural and mechanical tools of all kinds, firearms, &c. A few years will render us independent of all foreign nations for articles of this kind.

CHAPTER XXX.

MINERAL RESOURCES OF THE UNITED STATES —(Continued).

GOLD.

Extent of the Gold Region of the United States.—Gold-mines of Virginia—North Carolina—Georgia.

The gold region of the United States may properly be said to extend from the Rappahannock, in Virginia, to the Coosa in Alabama. Gold has, however, been found in Lower Canada, Vermont, Massachusetts, New-York, New-Jersey, Pennsylvania, and Maryland, and it is therefore supposed by some that the gold deposites follow the primitive formation from Canada to the Gulf of Mexico. At Somerset, in Vermont, Professor Hitchcock thinks there is every indication of a gold region, and that it probably extends south into Massachusetts, as it has been discovered at Deerfield.

The gold is chiefly found in veins of quartz, which penetrate the gneiss and other rocks composing the primitive formations which we described in a former chapter as extending from New-York to Alabama. It occurs also in the alluvium composed of the detritus of these auriferous veins and the adjoining rocks.

GOLD-MINES OF VIRGINIA.

Gold is found through several of the western counties of Virginia, particularly Spottsylvania, Orange, Louisa, Fauquier, Fluvanna, Culpepper, Gooch land, and Buckingham counties. It occurs in losse pieces in gravel, and also in veins with quartz, in mica, talcose, chlorite, or argillaceous slate, as these all seem to pass into each other. Professor Silliman, who examined the gold region of this state in 1836, states that the gold, when *in place*, occurs in *beds* or *layers* instead of veins which conform to the regular structure of the slaty rocks, and, like them, probably descend to unknown and unfathom able depths. "The material of the veins," says Professor Rogers, "is a variegated quartz, sometimes translucent, at others opaque. It is generally of a cellular structure, fractures without much difficulty, and, in many instances, contains a considerable proportion of water dispersed through its substance. Its surface, recently exposed, displays a variety of tints of brown, purple, and yellow, of such peculiar aspect as to resemble a thin lacker spread unequally over the rock. The cavities are often filled with a bright yellow ochre, a hydrated peroxide of iron, which generally contains gold in a state of minute division. Iron pyrites is another accompanying mineral, which in many mines occurs in considerable quantities."

The largest masses of gold have been found in, or near, rivulets or brooks, where pieces have been discovered weighing several pounds. On a branch at the Whitehall mine, gold of the value of ten thousand dollars was found in the course of a few days, in a space of about twenty feet square; and seven thousand dollars value of gold was found at Tinder's mine, in Louis county, in the course of one week. Much of the gold is contained in quartz, called *auriferous*, and, when in the rock, is invisible to the naked eye, being uniformly disseminated through it. From numerous carefully conducted experiments, Professor Silliman found that this quartz, when pulverized and melted, yielded at Busby's mine, on an average, an amount of gold equal to $8 16 for 100 lbs., or one bushel; at Moss's mine, what was equivalent to $7 70 for the same quantity; and at the Walton mine, the astonishing amount of $41 42 for 100 lbs. of the quartz. These trials were made upon ore selected at random, and such as was supposed to represent the average richness of that hitherto raised. When we consider that the expense of the whole operation of mining is but about 37 cents to the 100 lbs. of the quartz, or ore, we can form a pretty correct opinion as to the profits. It is, however, stated that the actual yield of the Walton mine is but about $6 to the 100 lbs., and of Fisher's mine $3 15 to the same quantity of ore. Any mine which yields $1 to the bushel is considered profitable, and as justifying heavy expenses in machinery and in operations of deep mining. Professor Silliman, in his "Remarks on the Gold-mines of Virginia," remarks, "That the gold region of Virginia, though of very unequal body, is, on the whole, rich in the precious metal admits of no doubt. That the Walton gold-mine and many others in Virginia, may be profitably wrought, is certain, provided that, in all cases, good judgment, sound economy, competent skill, adequate machinery, and strict fidelity, combine their salutary influence; otherwise the result may be calamitous, and the discovery of the precious metal in Virginia prove a curse instead of a blessing. There can be no reason, however, for believing that these interests will be abandoned. They will be pursued with sobriety, and, in many instances, with success. The enterprises are still in their infancy; experience will, in this case, as in other cases, prove the best instructress: in all probability, many rich gold deposites and gold veins remain to be discovered both in Virginia and in other states, and our country may confidently expect, from its own territory here and elsewhere, sufficient supplies of gold for its coinage, for the demands of the arts, of ornament, and of use, and not, improbably, for exportation."

GOLD-MINES OF NORTH CAROLINA.

These are situated in the southern part of the state, near the borders of South Carolina, and somewhat westward of the centre. The river Pedee flows through the gold region, which is spread over a space of not less than 1000 square miles. It includes the counties of Montgomery, part of Anson, and Muhlenberg, Cabarrus, and a corner of Rowen and Randolph. Throughout this district, gold may often be found in a greater or less abundance at or near the surface of the ground, enclosed in a dense mud of a pale blue or yellow colour. In low grounds it is found about eight feet below the surface; on elevated tracts it lies on or near the surface; but usually it is about three feet below the surface. The prevailing rock, according to Professor Olmstead, is argillite: others say it is talcose slate, which crosses the state in numerous beds, forming a zone twenty miles in width, and embracing beds of other rocks.

The principal mines are the "Anson mine," on a branch of Rocky River; "Reed's mine," in Cabarrus, occupying the bed of Meadow Creek; and "Packer's mine," on a small stream four miles south of the River Yadkin. At Reed's mine, a few years ago, a mass of gold was dug up by a negro which weighed twenty-eight lbs. avoirdupois. It is not uncommon to meet with masses weighing 600 pennyweights. The "mines" are generally rented out, and worked for a half, a third, or a fourth of the gold found, according to its productiveness. At Reed's mine, the average product is only sixty cents a day to each labourer. In the gold region, the uncoined gold is the common circulating medium. Every man, almost, carries about with him a goose-quill or two of the particles, and a small pair of scales, in a box like a spectacle-case The value is soon ascertained by weighing; and Professor Olmstead states that he saw a pint of whiskey paid for by weighing off two and a half grains of gold. The gold is generally bought up by the country merchants, who pay about ninety cents a pennyweight. Much of this is bought by jewellers; some goes into the banks; but the greater part goes into the United States' Mint.

Previous to 1820, but 43,689 dollars worth of American gold had been received at the Mint; and the first notice of North Carolina gold on the records of the Mint occurs in the year 1814, when a quantity was received to the amount of $11,000. It continued to be received till the year 1824, averaging about $2500 yearly. In 1824, the amount received was $5000; in 1825, $17,000; in 1826, $20,000; in 1827, $21,000; in 1828, $46,000; in 1829, $128,000; and during the same year, the amount from South Carolina was $3500, and that from Virginia $2500. Indeed, this was the first year in which any gold from these two states was received at the Mint. Thus nearly half of the tota amount of gold coined in the year 1829 was of domestic production. In the year 1830, $500,000 worth of gold was obtained in North Carolina by employing a capital of $150,000.

Previous to the year 1835, it was computed that the loose gold procured from washing gravel had yielded more than $6,000,000 of dollars, a great proportion of which, however, was worked up in jewellery, and not coined. These mines of Georgia had at that time yielded more than $500,000; and Mr. Taylor, an English practical geologist, who has examined the gold districts, anticipates that the gold deposites of the United States will soon yield far larger returns than those of Brazil, Columbia, and the Urals united.

GOLD-MINES OF GEORGIA.

Gold occurs in considerable abundance among the beds of gravel in the primitive region of Georgia, and also in veins in the same rock formation. The rocks are gneiss, mica, and talcose slate, hornblende and granite, and the gravel-beds, containing the ore which is at the bottom, are from one to four feet in depth. Above this gravel there is a bed of sand with scales of mica, varying from three to twenty feet deep, on a bed of clay with angular fragments of quartz, from one inch to five feet deep. The fragments of rock forming this gravel have the *rolled* appearance, which is produced by the action of running water, and chemical agents, evidently have resulted from the disintegration of the primitive rocks in the adjacent mountains.

The veins containing the gold traverse the original strata in various directions, but generally a little to the east and west of north and south. The veins are of quartz of different characters, varying generally with the original rock in which it is found; being sometimes crystallized in beautiful six-sided prisms, terminated by a pyramid at one end, and attached at the other to other crystals, or, more frequently, to a nucleus of feldspar. In some of the veins the quartz is compact, resembling horn flint; at other times it is crystalline, the fibres or crystals radiating from a central nucleus; and these various kinds of quartz are the gangues or matrices in which the gold is found. They also contain "iron pyrites," "brown oxide of iron," &c.

As to the mode of their formation, it is generally admitted that the fissures were produced by volcanic agency, and the quartz and elements of the metals were projected from below into the fissures producing the metals and their gangues. From late experiments, it is ascertained that galvanic electricity has much to do in the formation of metallic veins, and probably always is concerned in the production of these phenomena. It is difficult, indeed, to imagine how this agent can operate, unless the metals be compounds of gaseous bodies, which, by the combination of their simple elements, transmitted through conducting substances to immense distances, produce by their union the different metallic bodies. Thus we often see thin veins of gold in the centre of quartz crystals; how it got there in a solid form is more than we can explain, except on the above principle of its being a compound body. It is highly probable, and, indeed, all known facts bear us out in the assertion, that the deeper we penetrate the rocks containing metallic veins, the thicker and more valuable do the veins become. Still the vein may be so thin, that, after a certain depth, it cannot be profitably worked.

It is impossible to notice all the places where gold has been found in Georgia. It was about the year 1830 that public attention was directed to this subject, by the discovery of gold in Habersham county. It was soon ascertained that the whole of the eastern part of the Cherokee Country was a gold region, and the nation was run over by not less than 5000 gold hunters, while in Habersham and Hall counties 1000 more adventurers were seeking for hidden treasure. Numerous veins were found penetrating the solid quartz rock, and as individuals were too poor to work them, several companies were formed, which are now engaged in regular explorations.

The greatest quantity of gold has been found in the vicinity of a ridge of hornblende slate, which can be traced from Alabama, through the whole gold region of Georgia, a little east of the Blue Ridge, into North Carolina. The gold district of this state may then be said to occupy the whole of its northwestern part, and to extend probably far south, with an average breadth of from 50 to 80 miles. The other minerals found in this region are silver, lead, iron, titanium, copper, mercury? garnet, tourmaline, zircon, &c. Judge Peck remarks, "That the section described is immensely rich in metals, and the wise will no doubt turn this gift of Providence into a blessing; the country has as fine water or air as is drunk or breathed in the world, and there is much good land."

CHAPTER XXXI.

MINERAL RESOURCES OF THE UNITED STATES —(Continued).

Lead.—Copper.—Silver.—Manganese.—Peat.—Marl.—Granite Lime.—Gypsum.—Marble.—Salt.—Petroleum.—Carburetted Hydrogen.

A FULL account of the mineral riches of the United States would fill many volumes; of those which remain undescribed, we can briefly notice but a few.

Lead.—Lead is found in numerous places in the United States, but in few, however, in quantities sufficient to render its working profitable. It has been worked at Southampton and near Middletown (Connecticut), also in several places in Dutchess county (New-York), and at the Perkiomen Mine in Pennsylvania. The most valuable locality of this mineral in the State of New-York is at Rossie, in St. Lawrence county, where a vein two feet wide penetrates a ledge of rocks fifty feet high, and extends to an unknown depth.

One of the most extensive deposites of lead on the globe exists in what is called the Mineral District of Missouri, which comprises parts of the counties of Washington, St. Genevieve, Jefferson, St. Francis, and Madison, extending a distance of about seventy miles in length, and from the Mississippi, in a southwesterly direction, about fifty miles in breadth. Besides a great abundance of lead, this region contains also iron, manganese, zinc, antimony, arsenic, plumbago, &c. The lead ore is the galena or sulphuret of lead. It is found in loose detached masses in the soil, and not in veins, in rocks, as it usually occurs, and yields about seventy per cent. pure lead, and an annual product of several million pounds.

The total amount of lead from the United States lead-mines in Missouri, from 1825 to 1832, was 5,151,252 pounds; and from 1821 to 1836, the product of the lead-mines of Fever River amounted to 70,420,357 pounds, giving a total from both these sources of 75,571,609 pounds.

Copper.—Copper is found in many places in this country, in connexion with lead and zinc, as at the Perkiomen lead-mine* (Pennsylvania), Schuyler's

* There are indications of a rich deposite of copper nea. Rossie, St. Lawrence county, New-York.

mines (New-Jersey), Cheshire and Wethersfield (Connecticut), Singsing (New-York), &c.; but, as the quantity is too small to be worked in many places to advantage, we pass it by. The same remarks will also apply to silver ore, a small quantity of which is contained in nearly all our lead ores.

Manganese occurs frequently in the form of an earthy oxide, resembling bog iron ore, and is employed extensively in furnishing oxymuriatic acid for bleaching, communicating a violet or purple colour to glass, in painting porcelain, and furnishing oxygen gas. It has not heretofore been in great demand, but there is no doubt it exists in quantity sufficient to supply the wants of the country.

Peat.—Owing to the abundance of other kinds of fuel, peat has not yet been brought into extensive use, although it exists in inexhaustible quantities in many parts of the United States. Peat is derived from the vegetable fibres of partially decayed plants, or from decayed wood, which is called *ligneous* peat, though this is inferior to the other. The best peat lies at a depth of three or four feet, and frequently contains the trunks and branches of cedar and other durable kinds of wood, which have undergone little change. Though peat abounds in cold and wet regions, it is rarely found in warm climates, because vegetable decomposition is there too rapid to allow of the preservation of organic matter.

It is unnecessary to mention localities where this substance is found. Prof. Hitchcock estimates, that in the eastern part of Massachusetts 80,000 acres, or 125 square miles, are covered with it, being an average thickness of six feet four inches. This would yield at least 121,000,000 of cords. Prof. Mather remarks, "that peat is so common in every part of the first geological district (of New-York, embracing the southern part), that it may be found on almost every square mile. The value of peat-grounds is not yet fully appreciated; but when this combustible shall come into use, as it soon will, owners of those peat-lands which are convenient to a market must realize a large amount; and it should be remembered that these grounds, when dug once, are not exhausted like a coal-mine, but in a few years, if properly managed, will be renovated, and afford a new supply. A peat meadow, with a thickness of only three feet, will give more than 1000 cords per acre. This combustible may be furnished at so low a rate that the poor may have an abundance of fuel. The odour of peat is unpleasant to some persons, but not more so than that of bituminous coal. Peat is usually cut out in pieces like bricks, by a kind of spade with a raised edge on one side, and is then dried like unbaked bricks, and afterward stacked or housed for use."

Every swamp either contains peat, or a vast amount of vegetable matter which may be usefully employed in agriculture. It may also be employed for producing gaslight, as in France. Peat is often used for manure, after rotting it with lime in the barnyard or compost heap. Peat is not confined to fresh-water lakes and marshes, but also abounds in those which are salt. Mather estimates that the first geological district of New-York contains at least 3,000,000 cords of peat, some of which has as great a specific gravity as bituminous coal, and is nearly or quite as valuable for fuel.

"Perhaps it would be saying too much," says Prof. Emmons, "to assert that peat is more valuable than coal; but when we consider that it contains a gaseous matter equal in illuminating power to oil or coal gas, that its production is equally cheap, and, in addition to this, that it is a valuable manure if properly prepared, its real and intrinsic worth cannot fall far short of the poorer kinds of coal There is one consideration which commends itself to the philanthropic of all our large cities, viz., the introduction of peat as a fuel to supply the necessities of the poor. It is believed that much suffering may be prevented and much comfort promoted, by the use of peat in all places where fuel is expensive, as in New-York and Albany."

MARL.—There are two substances which go under the name of marl in this country, viz.: 1. The *Calcareous Marl*, composed chiefly of carbonate of lime. 2. The *Green Sand Marl*, which we have described in a former chapter.

The first kind of marl may be either a friable mixture of lime and clay, or partially decomposed beds of shells. In the New-England States, especially in the western part of Massachusetts, this marl often occurs in beds of from two to twelve feet thick, generally in marshes or on the borders of ponds. It seems to result from the carbonate of lime brought into ponds by water, and there deposited. After a while perhaps the pond fills up, vegetables begin to grow over the marl, and thus at length a deposite of peaty matter covers the marl. When dry, this substance is nearly as white as chalk, and much lighter than common soil; when wet, it is of a light gray colour, especially if it contains much organic and earthy matter; the quantity of lime it contains may generally be told by its degree of whiteness. Prof. Hitchcock states that this marl is found almost exclusively in swampy ground, generally quite wet swamps, and always covered by a stratum, often several feet thick, of black vegetable matter approaching to peat. Hence, as these swamps are not easily excavated, the marl is not apt to be discovered. Prof. H. recommends passing down an iron rod several feet long, with a groove in the end like an auger, in order to discover marl in places where it is suspected; or even a rough pole, which he says answers the purpose just as well, some of the substance always adhering to to it when withdrawn. There is a kind of clay produced by the decomposition of feldspar, which closely resembles marl; it is, however, easily distinguished by its not effervescing when mixed with vinegar, oil of vitriol, or any other acid, as marl does. This substance contains from 40 to 95 per cent. of carbonate of lime, with a quantity of vegetable matter, sand, phosphate of lime, and a trace of magnesia. Its immense value as a fertilizing agent will be noticed in the ensuing chapter.

We have already described, at sufficient length, perhaps, the localities of the *green sand marl*, which forms a deposite over nearly the whole southern half of New-Jersey. It has been traced in many places through the Atlantic States to Alabama, and has lately been discovered by Professor Hitchcock in Massachusetts, and by Dr. Troost in Tennessee. The green marl of Massachusetts consists chiefly of *silex*, *alumine*, and *oxide of iron*, and does not contain potash like that of New-Jersey: hence there is much doubt as to its possessing such powerful fertilizing properties as that of the latter. This can only be tested by actual experiment. The marls of Virginia and the Middle States, however, are chiefly of the *miocene* era, and composed of carbonate of lime (mostly derived from shells), from 12 to 90 per cent.

Granite.—We have given so full a description of the granite formation in the United States, that little need be added in this place. For building purposes, no country in the world possesses such an inexhaustible quantity and variety of granite rocks as New-England; none more durable in structure, or beautiful in appearance.

Of the Eastern States, Maine is pre-eminent for the abundance and excellent quality of her various granite rocks, which offer facilities for quarrying and exportation unequalled by those of any other part of the known world. Here all varieties are to be met with, from porphyry and syenite, more beautiful than that of Pompey's Pillar or Cleopatra's Needle, to the close-grained, compact granite so often seen in the public buildings of New-York and Boston. Situated directly upon navigable waters, it can be quarried and transported to market cheaper than perhaps any building material in the country; many of the quarries of Maine, Dr. Jackson states, can furnish unhewn blocks of any size, on board ship, for $1 12 per ton, and the expense of transportation to New-York is rarely more than $2 50 per ton. As the article in any of our principal cities is worth $7 per ton, this will give a profit of $3 38 for each ton of granite. Masses suitable for columns command about 90 cents per cubic foot; so that a column similar to those of the New-York Exchange costs $1500. At Kennebunk, rough-split granite sells for $5 per ton of 14 cubic feet on the wharf. The price remains uniform up to the dimensions of 26 cubic feet, and above that measure, two cents per foot is charged for every additional foot. Stones for store fronts, hammered, sell for 75 cents per superficial foot; and where two sides of a stone are fine dressed and two rough hammered, three sides are charged, and nothing is demanded for the ends. Where three sides are fine dressed and one rough hammered, they charge for four sides and not for the ends. Numerous and very extensive quarries of granite are now worked both in Maine and Massachusetts, which are a fruitful and increasing source of wealth to the inhabitants.

In the State of New-York we find mountains of granite and gneiss, and various modifications of these rocks, especially in Dutchess, Putnam, and Westchester counties. Prof. Mather states, that "there are many places in these counties where quarries may be opened, which would afford building materials of the best quality, and which would endure the changes of our durable climate for ages, without decay or disintegration. The naked crags and masses of rock afford irresistible evidence on this point. These rocky hills and mountains, worthless as they now seem to most persons, undoubtedly contain the best of building materials. The quarries which will be opened will form an important branch of industry, and will enable our citizens to construct both public edifices and private dwellings of our own native materials, and which are as durable and beautiful as those now brought from Maine, Massachusetts, and Connecticut, at so great an expense."

Lime. — Lime is the well-known product from limestone, its carbonic acid being driven off by heat, and is an indispensable article in architecture, engineering, &c. As the material from which it is obtained is inexhaustible in the United States, the quantity of lime annually manufactured is only proportioned to the demand; in other words, to the amount consumed. From statistical facts collected by Dr. Jackson, it appears that the quantity of lime annually manufactured in the State of Maine exceeds 700,000 casks, which sells for one dollar a cask, thus amounting to a larger sum than the whole annual produce of the gold region of the United States, and that, too, without risk, and with a certain return of profit. The town of Thomaston alone manufactures more than 300,000 casks; the cost of burning being about $160,000, it requiring 40,000 cords of wood, the average cost of which is $3 per cord. Lime casks cost 28 cents a piece, quarrying seven cents per cask, and rock in the quarry three cents; the average quantity of lime burned in a kiln is 300 casks. In many places in Maine, lime is burned where wood costs but 75 cents per cord; which makes a considerable difference in the expense. Seven eighths of the Thomaston lime is transported to different markets in vessels belonging to the place and manned by her own citizens; and of these vessels Dr. Jackson states that more than 100 are constantly employed. The measure of a lime-cask is fixed by law at 40 gallons, and they hold 300 lbs. of lime. A kiln capable of burning 300 casks of lime is 14 feet long, 14 feet high, and five feet deep. It has three pointed arches,* that in the centre being five feet high. The kilns in Maine are usually built of talcose slate.

Lime is burned very extensively on the Hudson River, particularly at Barnegat, where the kilns are kept constantly burning from the opening of the river in the spring until the closing of it in winter, without allowing them to cool. The method pursued here is, after the kiln is once kindled, to charge about half a ton of anthracite coal, broken to the egg size; then 300 to 350 bushels of limestone, in lumps of 20 to 30 pounds each; and at the end of 12 hours another charge of coal and limestone, and so on till the kiln is filled. They then draw out about 850 bushels of lime from the bottom, and introduce another charge of coal and limestone, and every 12 hours this process is repeated. This operation is continued for months, as in a furnace for smelting iron. A great economy is thus introduced; the kilns being always kept heated, and the heat which would escape in the common mode of manufacture is here expended in heating other portions of limestone, and preparing it for the high temperature necessary to expel the carbonic acid. About 700 bushels of lime are thus obtained daily from each kiln, with the consumption of a little less than

* "There are many improvements," says Dr. Jackson, "to be made in the method of burning lime, and one of these contrivances consists in having lateral arches, in which the wood or coal is consumed, while the flame and current of heated air draw through the limestone, and keep it constantly red-hot. It is then, when sufficiently burned, drawn out, and more rock is to be added to the top of the charge."

a ton of coal. As coal costs but $6 per ton at the kiln, the expense of fuel is less than one cent per bushel; whereas, where wood is used, the expense is considerably more. Lime is sold on the wharf at six cents a bushel. The limekilns of Dutchess county yield 1,500,000 bushels of lime annually, worth $93,750, at a nett profit of at least $30,000.*

GYPSUM.—Sulphate of lime, or gypsum, occurs under a variety of forms, viz., in large, transparent, crystalline plates, or radiated fibres, or snow-white masses: most usually it is found in fine or coarse grained compact masses, forming rocks, and constituting large and extensive strata. Its colours are white, red, brown, bluish white, &c. It is the last variety of this mineral that constitutes the beds so often met with among secondary rocks, particularly the salt and coal formations. It rarely occurs among primary or transition rocks, and is almost always associated with salt. It contains but few organic remains, and those that occur are chiefly bones of quadrupeds, amphibia, fresh-water shells, and vegetable remains. Caves are of frequent occurrence in gypsum. The purer semi-transparent specimens of gypsum are used for ornamental works, as vases, urns, &c., and for statuary; for which purposes its softness makes it very useful and easy to work: but this quality renders it difficult to polish. In this last form, it is the alabaster of the arts. It constitutes the material used in making the fine plastering for the internal finishing of costly edifices, and gives the walls a most beautiful whiteness. It is also used, after being burned, for the composition of stucco-work of all sorts. But the great and important use of gypsum, or *plaster*, as it is usually called, is for manuring grass and grain lands, for which it is truly invaluable.

Gypsum occurs abundantly in New-Brunswick

* Professor Mather's Report, &c.

and Nova Scotia, where more than twenty extensive quarries are worked, and the material exported to Boston, New-York, and other places. In the State of New-York, gypsum is abundant, particularly in Onondaga and Madison counties, and in the vicinity of Cayuga Lake, whence several thousand tons are annually exported to Pennsylvania. The gypsum of New-York is often connected with compact limestone and calcareous sandstone, and at Manlius it alternates with an argillaceous slaty rock; at the Helderberg it is connected with calcareous sandstone. Indeed, gypsum-beds extend on both sides of the Erie Canal, along the southern part of Wayne county, but generally too low for profitable exploration. At Clyde, it lies 25 feet below the surface; at Lyons, 40 feet; at Palmyra, the same. Near Newark, a reddish variety, consisting of large, round, and irregular masses, is quarried which sells for from $2 50 to $3 per ton. That which is transparent is called *isinglass plaster*, and, though often rejected as useless, is the most valuable kind of all. A stratum of gypsum extends also across the southern part of Monroe county, occupying all that portion south of Black Creek, and between it and Allen's Creek. In the town of Wheatland, about 5000 tons are annually obtained, part of which is used on the land in the county.

The gypsum of New-York is contained in the calciferous slate of Eaton, which, by consulting our table of equivalent formations, will be found very low down among our rocks, indeed, next to the graywacke slate of Hudson River. In excavating for the Syracuse railroad, about 40,000 tons of gypsum were thrown out between Camillus and Auburn, estimated to be worth $35,000. Indeed, the gypsum is exposed at various points in the excavations for the distance of five or six miles. In the

Valley of the Ohio gypsum is nowhere found accompanying the rock-strata near the surface of the earth, though indications of it are discovered at great depths below, especially at the works on the Muskingum River. "Gypsum," says Dr. Hildreth, "is deposited in extensive beds on the borders of the valley, in the secondary and transition rock at the surface, and may be deposited beneath the series of sandstone and coal, deep in the earth throughout the whole valley. It is seen in great abundance along the southern shore of Lake Erie, near Sandusky, and in various other intermediate places, quite to the borders of New-York, and in the interior of that state, being found at intervals from the shore of the lake to the mountain ranges. At the salt-works on the heads of the Holstein, it is discovered in great abundance, appearing partly to encircle the salt region with a cordon of deposites."

Marble.—There are many beautiful and valuable marbles obtained in different parts of the United States. The Latin word *marmor*, from which the term marble is derived, was applied by the ancients to all stone susceptible of a fine polish, but at present the word is confined to such varieties of carbonate of lime as are susceptible of polish. Both *granular* and *compact* limestone furnish numerous varieties of marble, but those which belong to the *former* exhibit a more uniform colour, a greater translucence, and are generally susceptible of a higher polish, and, therefore, are most esteemed for statuary and other purposes.

The uniformity of colour so common in primitive marble, is sometimes interrupted by spots, or veins, or clouds of different colours, arising from the intermixture of hornblende, serpentine, talc, chromate of iron, &c.

Vermont and the western part of Massachusetts abound in white and gray marbles of great excellence and durability. Some of the Vermont marbles are as white as the Carrara or statuary marble, receive a fine polish, and are extensively wrought for tombstones, chimney jambs, window caps, and other purposes.

The Stockbridge marble is well known, as the City Hall of New-York is built of it. It is a pure white, moderately fine grained, and very durable. The Lanesborough and Sheffield marble is very similar, and from the Sheffield quarries the marble is obtained which is now employed in the erection of the Girard College at Philadelphia. "A visit to this quarry," says Professor Hitchcock, "will give one, perhaps, the best idea of the value and extent of the Berkshire marbles, and, at the same time, of the power which the arts give to man over nature. To see masses more than fifty feet long, and six or eight feet thick, split out by the apparently feeble means employed, makes a strong impression on the mind, and recalls the history of the enormous blocks of stone quarried and removed by the pyramid builders of antiquity." It may with safety be said, that no marbles in the United States exceed in elegance and durability those of Berkshire county. The value of all the marble now exported from that county cannot be less than $70,000 annually, and the beds are inexhaustible.

A very beautiful marble is obtained from near New-Haven (Connecticut), called the *verd antique* when it contains green colours, though its predominant colour is gray or blue, richly variegated with veins or clouds of white, black, or green, the last of which sometimes pervades a large mass. Some specimens exhibit clouds of a brilliant orange or gold yellow, associated with green serpentine and dove-coloured limestone. The black clouds and spots are occasioned by magnetic oxide of iron and chromate of iron, and green and yellow serpentine is also disseminated among it. There are four chimney-pieces of this marble in the Capitol at Washington, which cost about $500 each. When formed into slabs for tables, it costs from $4 to $5 per square foot.

New-York abounds in valuable marbles, especially Dutchess and Columbia counties. Limestone abounds throughout the extent of both these counties; it is granular and compact, white, gray, clouded, striped, and nearly black. Marble is extensively wrought in Dover, from whence about 40,000 feet of marble slabs are sent annually, which yield an income of 30,000 dollars. The marble employed in building the New-York Custom House is from White Plains, Westchester county. It is a very white, coarse-grained marble; its durability remains to be tested. Marble is also obtained from Kingsbridge and Singsing, but of an inferior quality. The University of the City of New-York, as well as the State Prison buildings at Singsing, were built with the latter, but it has every appearance of being rapidly decomposed by the chemical and mechanical agents to which it is exposed.

The Potomac marble is obtained on the banks of the Potomac River, about fifty miles above the City of Washington. It is what is called a *breccia marble*, consisting of fragments, varying in size from that of a grain of sand to half a foot in diameter; and their forms being angular, rhombic, rounded, oval, &c., and of various colours, as white, gray, yellow, reddish brown, blackish, &c., present a very beautiful appearance when polished. The shafts of the columns in the Representatives' Chamber, in the Capitol of the United States, are formed of this marble; they are nineteen feet nine inches in height from the base to the capital, and two feet in diameter; some of them being composed of one entire mass. Indeed, a block seventy feet long, with a base eleven feet by seven, has been obtained at the quarry Our limits allow no farther description of the marbles of the United States: we may, however, remark, that no country on the globe can furnish a greater variety, or those of a more beautiful and durable character.

Salt. — Saline springs abound in the State of New-York and in the Valley of the Mississippi. Onondaga and Cayuga counties are particularly rich in this mineral; and brine-springs have been found for upward of 100 miles, in a range a little west of north of a line drawn through Lenox, Madison county. There are at present near Onondaga Lake four wells and pump-works for the raising and distributing of brine, under the direction of the state authorities, viz., one at Salina, another at Syracuse, a third at the village of Geddes, and a fourth near Liverpool. At Salina the well is 70 feet deep, and the brine is raised by forcing-pumps high enough to fill a reservoir, which supplies the salt-works of the village, as well as, occasionally, those at Syracuse and Liverpool. Dr. Beck states, that this well affords more brine than all the others, and that the pumps raise 482 gallons in a minute, or 28,920 gallons in an hour. The temperature of the brine, which is perfectly limpid and sparkling, is 50° (Fah.), and it requires 43 1-2 gallons to yield a bushel of salt, weighing 56 lbs. The well at Syracuse is 170 feet deep; temperature of the brine, 51° Fah.; the pumps raise 62 gallons in a minute, and 46 gallons make a bushel of salt. In boring for the Liverpool well, which is 50 rods from Onondaga Lake, the strata passed through were marl, 12 feet; fine sand, 14 feet; fine clay, 43 feet; gravel, 81 feet; total, 150 feet. The brine at these wells is chiefly evaporated by boiling in large iron kettles. Solar evaporation also is employed to considerable extent, and likewise *steam*, which is passed through the vats in tubes. This furnishes salt in fine cubic crystals, of great purity.

The quantity of salt ma factured in the United

States in 1829, was 3,804,229 bushels; of which the Onondaga springs furnished 1,291,220 bushels. In 1835, the amount of salt made at these springs was 2,222,694 bushels; so that, reckoning the total amount of salt manufactured in the United States, at present, to amount to 8,000,000 bushels, the springs of Onondaga furnish more than one fourth of the whole. The following statement exhibits the relative strength of the different brines from which salt is made in the United States: One bushel of salt is obtained from 450 gallons of sea-water at Nantucket; 450 gallons of brine at Boon's Lick (Missouri); 300 do. Conemaugh (Penn.); 280 do. Shawneetown (Ill.); 213 do. Jackson (Ohio); 180 do. Lockhart's (Mississippi); 123 do. Shawneetown; 120 do. St. Catharine's (U. C.); 95 do. Zanesville (Ohio); 75 do. Kenawha (Virginia); 80 do. Grand River (Arkansas); 50 do. Muskingum (Ohio); 41 to 45 do. Onondaga (N. Y.); thus showing that the saline springs of New-York are the strongest yet discovered.

Prof. Beck, in his able Report to the Legislature, from which these facts are gathered, maintains, with great plausibility, that these salines originate from a solution of beds of rock-salt, at a considerable distance below the surface, and recommends deep borings to ascertain the fact. We have not space for his arguments, which are numerous, and to us perfectly conclusive. The valleys of the Ohio and Mississippi abound in saline springs of various degrees of strength. Indeed, nearly, if not entirely, the whole valley of the Ohio is based on saliferous or muriatiferous rocks, which afford an abundance of water highly charged with muriate of soda. We find it stretching along the base of the Alleghany range of mountains, amid the coal and sandstones of that region; and Dr. Hildreth supposes that it extends far north to Lake Erie, though at a considerable depth. The rock which furnishes the water is a white, porous sandrock, sometimes tinged with red. On the Muskingum there are two distinct strata of this rock, known as the upper and lower salt-rocks, the distance between them being over 400 feet. The upper is 25 feet thick, and the lower 40; it is this which furnishes the strongest brine and in the greatest quantity. This rock lies at different depths in the "valley," being deeper near its centre or most depending portion, and rising nearer the surface on its borders. On the Muskingum it is 800 feet below the surface; on the Kenawha, 400. Thus, at the former place, it lies far below the present surface of the ocean, it having been pierced at 900 feet, which is 300 below tide-water at the mouth of the Mississippi.

Throughout the Muskingum Valley, a distance of sixty geographical miles, the saline rocks sink deeper and deeper into the centre of the valley, from a depth of 250 feet to that of 1000. Thus, at Zanesville, salt water is obtained at 350 feet; at Taylorsville, nine miles below, at 450 feet; at M'Connelsville, eighteen miles below, 750 feet; and at Bald Eagle at 1000 feet. The strength of the brine also increases in nearly the same ratio; so that fifty gallons from the lower wells afford as much salt as two hundred and fifty from the upper ones. There are at present on the Muskingum about seventy brine-wells, and as many furnaces, which manufacture annually about half a million bushels of salt. The salines on the Kenawha furnish about 1,500,000 bushels per annum. On the Holstein, the saline wells are from 200 to 300 feet deep.

Petroleum and Carburetted Hydrogen.*— Petroleum is a mineral oil, the product, as is supposed, of the vegetable decomposition which produces bituminous coal. A similar article is produced by

* From Dr. Hildreth's Report to the Legislature of Ohio, 1838.

the distillation of bituminous coal; by the ignition of wood, as happens in preparing charcoal in iron cylinders for the manufacture of gunpowder; and also in the making of pyroligneous acid. Petroleum, then, and carburetted hydrogen gas, may be considered as the products of the beds of bituminous coal which lie deep in the earth, and are generally found to accompany the salt water in greater or less quantities. Where gas is discharged freely, it greatly assists the ascent of the water in the wells, and saves the expense of forcing it up by the aid of a pump worked either by horse or steam power. If constant and abundant, Dr. Hildreth states that it might be conducted by pipes under the kettles, and used as a fuel in boiling away the brine, thus relieving one of the heaviest items of expenditure in working a furnace. In some wells in Ohio the discharge of gas is periodical, and at intervals of eight or ten days, bringing up with it large quantities of petroleum, to the amount of several barrels. In some the discharges of gas are tremendous, throwing the water all out of the wells to a height of thirty or forty feet. The eruptions are attended by a flow of petroleum, which in some instances has amounted to from thirty to sixty gallons at each flow, and returning at intervals of two to four days. The salt wells now average only about a barrel a week. At a locality near the gravel coal-beds on the Hockhocking, the earth and rocks have been blown out to a considerable distance, leaving a cavity of several feet in diameter and depth. Probably the true reason why saline fountains are commonly attended by inflammable gas is, that the coal formation and salt deposites are, geologically, close neighbours, the salt being usually *above* in Europe and other countries, but *below* in the Valley of the Ohio and its confluent springs. This fact also lends great force to the opinion that the coal formation does not exist in this state.

This compound gas is the same which collects in the coal-mines in England, and proves so fatal to the miners.

CHAPTER XXXII.

PRACTICAL APPLICATION OF GEOLOGY TO THE USEFUL PURPOSES OF LIFE.

Architecture.—Engineering—Roads—Canals—Embankments—Wells—Mining.—Agriculture.

Geology derives its chief importance from its application to many of those arts which minister to the comforts and necessities of man. A knowledge of the formation and structure of the earth not only gratifies a rational curiosity, but it directly places within our reach the instruments by which its useful materials may be converted to highly valuable purposes. Here knowledge truly is power; and he who is thoroughly conversant with geological principles and facts, possesses the lever and the "where-to-stand" which Archimedes wanted to move the world.

ARCHITECTURE.

It would seem that the importance of knowing and testing the durability of building stones and marbles for public works, or even private dwellings, is too obvious to need remark; and still there has hitherto been displayed great ignorance or inattention to this subject in this country, so much so, that frequently the worst and most perishable materials have been selected in preference to such as are equally beautiful, and, in addition, indestructible.

Without multiplying instances, we may refer to the aqueduct at Rochester, which is already in a state of dilapidation from exposure to the elements; and we could name a splendid public building, erected from the crumbling marble of Singsing, which promises an equally short-lived existence. It is a dictate of common sense, that a knowledge of the general structure of rocks, and the situations whence the best materials may be obtained, is essential to the builder and such as are charged with the erection of public works. A few hints on this subject are all we have space to offer.

A stone which is sufficiently durable under water may not be so when kept alternately wet and dry by the rise and fall of water in a river, or canal, or on a tidal coast, or even when wholly exposed to the atmosphere. If it be a porous sandstone, it will probably last well if constantly under water; but, if exposed to the air, the same rock will be certain to crumble in climates subject to frost. Owing to inattention to this simple fact, many of the finest national structures of England, where there abounds an almost inexhaustible variety of rocks of the most imperishable quality, have gone to premature decay. "It is painful," says Philips, "to mark the injuries effected by a few centuries on the richly sculptured arches of the Normans, the graceful mouldings of the early English architects, and the rich foliage of the decorated and later Gothic styles. The changing temperature and moisture of the air, communicated to the slowly conducting stone, especially on the western and southern fronts of buildings, bursts the parts near the surface into powder, or, by introducing a new arrangement of the particles, separates the external from the internal parts, and causes the exfoliation or desquamation of whole sheets of stone parallel to the ornamental work of the mason From these attacks no shelter can wholly protect the parts of a building which are below a ledge of ten decay the first; oiling and painting will only retard the destruction; and stones which resist all watery agency, and refuse to burst with changes of temperature, are secretly eaten away by the chemical forces of carbonic acid and other atmospheric influences." The same writer remarks, "There is no doubt that very great benefit would result to the building art if the whole kingdom were surveyed by geologists and architects, for the purpose of determining generally the occurrence and qualities of stone suited for great and costly edifices." In accordance with this suggestion, a commission was issued by the British Parliament, appointing the able geologist, Mr. De la Beche, and an architect, to select for the new houses of Parliament the best material for this national work, and they have already reported. It is hoped that this example may not wholly be lost to this country.

A very good mode of judging of the durability of rocks is to observe the effects of the atmospheric influences in the locality whence the rock is obtained. Its appearance, especially if it be a compound rock, will readily indicate whether it is easily acted upon by these causes, or the reverse. For example, if the rock be a granite, and it be very uneven and rough, it may be inferred that it is not durable; that the feldspar, which forms one of its component parts, is more readily decomposed by the action of moisture and frost than the quartz, which is another ingredient; and, therefore, that it is very unsuitable for building purposes. Moreover, if it possess an iron-brown or rusty appearance, it may be set down as highly perishable, owing to the attraction which this metal has for oxygen, causing the rock to increase in bulk, and so disintegrate. This may be seen in much of the granite which is quarried in the Eastern States, but not in all. The syenitic granites of Quincy and other places, which contain a very compact species of feldspar and but little iron, are as durable rocks as this country anywhere affords.

All rocks which readily absorb moisture, such as our red sandstone or *freestone*, are very perishable. This may be seen by examining the tombstones of this material, which were formerly employed to considerable extent in this country; their inscriptions will generally be found illegible. In many buildings in this city (New-York), the surface of walls constructed with it is often rough and unseemly, owing to its absorbing moisture, which, on freezing, peels it off in flakes. There is, however, a great difference in freestone in this respect, some of them not possessing great porosity, and, of course, are more durable. Regard, however, should be paid to the several beds of which a rock is composed. It does not follow that, because one portion of a rock is perishable, the whole of it is so. For example, Philips states that Roman sculptures remain at Bath and York, executed in oolite, magnesian limestone, and millstone grit, which yet retain all their characteristic perfection; while other rocks of the same species have perished in churches and houses in less than 100 years. Many other similar facts could be given to show that the different beds of a rock are of very unequal value. As certain trees will bear the ocean air and others not, so with stone; it is not equally durable in all situations, but yields variously and unequally to carbonic acid, smoke, dampness, and salt vapours. As a general rule, we think it will hold good, that the durability of building-stone may, in a great measure, be estimated by the quantity of water which it absorbs; that which imbibes the most being the most perishable, and *vice versa*. The durability of sandstones depends much, however, on the cement with which the small particles are bound together. If it be silicious, the stone will prove more durable than if it be calcareous; in which case it is readily acted on by the carbonic acid contained in the atmosphere; if argillaceous, as in many kinds of graywacke, it will also be readily decomposed, and the stone become a mass of sand and clay.

The Pyramids of Egypt are built of granite, though some travellers say of a grayish calcareous stone containing shells. The Parthenon and other public buildings of Athens, which have withstood the action of the elements during the lapse of more than 20 centuries, are of Pentelic marble. The mosques of Constantinople are of a fine-grained limestone, similar to that which is now used in lithography. The Coliseum, and St. Peter's Church at Rome, are built of travertino, a calcareous stone deposited from water. The ruins of Paestum are built of the same. The building called the tomb of Theodric, at Ravenna, has a dome of limestone, consisting of a single stone 34 feet in diameter, and weighing more than two million pounds. The houses in Paris are chiefly built of a calcareous stone. St Paul's, and many of the public buildings of London, are constructed of oolite, called Portland stone, a calcareous rock which we have already described. Most of the ancient statuary is formed of Parian marble. The pedestal of the statue of Peter the Great, at St. Petersburgh, weighing three million pounds, is of granite. Sixty granite columns of St. Petersburgh consist each of a single stone 20 feet high. Pompey's Pillar, in Egypt, is 63 feet in height, composed of a single piece of granite.

ENGINEERING.

An accurate knowledge of the physical and chemical properties of materials is no less important to the engineer than to the architect. Indeed, as he is employed in the construction of public works, such as railroads, canals, aqueducts, roads, bridges, embankments, quays, dikes, sea-walls, &c., whose value will be proportioned to their solidity and durability, it is essential that he should understand the absolute and relative strength of materials, the resistance they offer to friction and shocks, the changes which they undergo from exposure to the atmosphere, and to the more ordinary chemical agents, such as fire, salt water, &c., as well as the time and labour required in preparing them for the purposes of building.

Roads.—It has been well remarked, "that the expense of constructing a new road, or of maintaining an old one in good order, greatly depends upon the kind of ground under it, upon the facility with which proper stone may be obtained for it, and upon the stability of the various cuts which it may be found necessary to make in the rocks, is well known. It is not, however, so well known, that these circumstances depend upon the geological structure of a country, and that a knowledge of this structure would enable those who possess it to determine whether one line of a new road would be more costly than another; whether, when it becomes a question to patch up an old line of road or construct a new one, the one or the other will be ultimately found least expensive; and that some kinds of stone should be employed upon roads in preference to others, when several kinds can readily be obtained." An attention to these particulars, however unimportant they may appear to some, would save in this country many thousands of dollars annually. Those who have travelled much, and seen how our roads are constructed and repaired; how, in some places, a soft, perishable stone is brought from a distance, when a far better material is close at hand; how slatestone and graywacke are often beaten up, and used either for the foundations or repairs of common or even Macadamized roads, which are soon pulverized, forming an impalpable dust in dry weather and a miry clay in wet, will need no argument to convince them of the total inattention paid to this subject.

In laying out roads, attention should be paid not only to levels and distances, but to the nature of the country through which the road is to pass, and the facilities of keeping it in repair; and, in choosing materials for its construction, we are to recollect that the stones placed on them are not only exposed to friction, but also to the pounding or crushing action of the weights which roll over them; and, consequently, that a tough as well as hard substance is required. Rocks which are composed of minerals of unequal degrees of toughness are greatly inferior to those which are of the same texture throughout. It is owing to this circumstance that *granite* affords roadstones far inferior to those of the *trap rocks*. In the City of New-York, the granite has latterly been extensively introduced as a paving-stone where the walks intersect the streets; but the slightest attention will show that it is most rapidly pulverized by the friction to which it is constantly exposed from horses and carriages; and not only this, but the kind employed is a coarse and very inferior granite, containing much iron; and we have frequently seen masses of it employed for the above purpose, changed to a brown colour by oxidation of the iron for a distance of from five to twelve inches from the surface. Such stones, in such a situation, can last but a short time. De la Beche remarks, that "trappean rocks have lately been imported into London for the purpose of stoning some roads; and no doubt those who have done so will find that, though the trappean stones cost something more in the beginning, they cost less in the end, since their durability is greater than that of the granites." The coarser granites are the most perishable, whether employed for roads or buildings; while the finer varieties of the syenite, in which the hornblende prevails and the feldspar is compact, will be durable. The most valuable materials for roads in this country are the greenstone, trap, and hornblende rocks, though even these possess different degrees of toughness from the same quarry. We may form a very correct estimate of the comparative toughness of different stones, by pounding a small piece in an iron mortar. By using tough materials, especially in the construction of Macadamized roads, we not only reduce the expenses of their maintenance, but also the annual amount of hinderance caused by the more frequent supply of rough, new stones, which tend so much to retard the progress of wheel carriages, and add to the labour of the horses which draw them.

Canals.—A knowledge of the geographical structure of a country through which a canal is to pass, is no less necessary than in that of roads. Those only who possess this knowledge can judge as to the probability of meeting springs of water, of the porous or impervious character, as regards water, of the rocks to be traversed, and the kinds of rock which will be encountered in cutting, and the facility with which these may be removed. The geologist only can estimate justly the value of the various mineral substances which may be advantageously brought to the canal for the purposes of traffic, such as coal, iron, marble, and other minerals.

Estimates for canals in this country vary, very often, wide from their actual cost, from the fact that some of the rocks traversed readily absorb water, rendering it necessary to incur the expense of making the canal-bed water tight. A little knowledge of the nature of rocks in this respect, and the geological structure of the country to be traversed, would enable the engineer either so to locate the canal as to avoid such rocks, or, if that is impossible, to make proper allowance in forming his estimates of the expense. In such cases, it is evident that a knowledge of rocks on the surface is not sufficient; he must know what rocks lie at the different depths to which the canal must be cut, and to this end he must be acquainted with the order of succession of the different strata.

Embankments.—In the construction of roads and canals, walls and embankments often have to be erected; and from the frequent repairs needed on our canals from the sliding of embankments, we apprehend they are often constructed without regard to those rules and principles, on the observance of which durability alone depends. Sir Henry Parnell remarks, that "great care is necessary in making high embankments; no person should be intrusted with these works who has not had considerable experience as a canal or road maker; for if the base of an embankment is not formed at first to its full breadth, and if the earth is not laid on in regular layers or courses not exceeding four feet in thickness, it is almost certain to slip.

"There have been but few attempts to make embankments by turnpike trustees that do not afford illustrations of this defect, and of a want of knowledge of the proper rules by which these works should be managed. No doubt a chief reason for making cuttings and embankments, as is frequently the case, with slopes of one to one, has been to save expense in the purchase of land and moving earth; but the consequence of making such slopes is, that the earth is constantly slipping, so that, in the end, the expense is always greater in correcting the original error than it would have been had proper slopes been made in the first instance. The slopes at which cuttings and embankments can be safely made, depend entirely upon the nature of the soil. In the London and plastic clay formations, it will not be safe to make the slopes of embankments or cuttings that exceed four feet in height, with a steeper slope than three feet horizontal for one foot perpendicular. In cuttings in chalk or chalk-marl, the slopes will stand at one to one. In sandstone, if it be solid, hard, and uniform, the slopes will stand at a quarter to one, or nearly perpendicular. If a sandstone stratum alternates with one of clay or marl, it is difficult to say at what rate of inclination the slopes will stand; this will, in fact, depend upon the inclination of the strata. If the line of the road is parallel to the line of the bearing of the strata, in such cases large masses of the stone become detached and slip down over the smooth and glossy surface of the subjacent bed. There are many instances of slips in sandstone and marl strata, under such circumstances as those now described, where the slopes are as much as four to one. If the road is across such strata, or at right angles to the line of bearing, the slopes may be made one and a half to one; but if the strata are horizontal, even should there be thin layers of marl between the beds of stone, the slopes will stand at a quarter to one. But it will be necessary, if the beds of marl exceed twelve inches in thickness, to face them with stone. In the Oxford clay, which covers so great a portion of the middle counties of England, the slopes should not be less, in any instance, than two to one, and even in some parts of this formation they should be made three to one if the cuttings are deep. In all such cases, if any beds of gravel or sand are found intermixed with the clay, drains should be cut along the top, and even in the sides of the cuttings; for if this precaution be not taken, the water, which will find its way into the gravel, will, by its hydrostatic pressure, force the body of clay down before it, and slips will take place even when the inclinations are as much as four to one; and, when this occurs, it is extremely difficult to re-establish them. In limestone strata, if solid, slopes will stand at a quarter to one; but in most cases limestone is found mixed with clay beds, and in such cases the slopes should be one and a half or two to one. In the primitive strata, such as granite, slate, or gneiss, slopes will stand at a quarter to one. In every instance of deep cutting, the greatest pains should be bestowed in examining the character of the material to be removed, as much difficulty will be avoided by proceeding this way."

Wells.—The application of geological knowledge to obtaining water by the sinking of wells, is too obvious to need remark. The depth and abundance of springs, the quality of the water, and its ascending power, depend entirely on geological causes, and can only be estimated with correctness by the practical geologist. Since the construction of Artesian wells, by boring the earth with an iron or steel rod, it has been found that very go d water may be procured in situations, which, for the want of it, were formerly considered uninhabitable, such as the deserts of Africa, Arabia, and Mesopotamia. Some local situations are highly favourable to the formation of Artesian wells; in others, on the contrary, there is scarcely a probability of success; in some places a small depth will be sufficient to obtain water, in others the depth must be very considerable; and these are questions which can be decided by geology alone. It would be very easy to enumerate many cases of failure and great pecuniary loss in works of this kind, merely from neglecting these obvious precautions, and a due examination of the spot by competent persons previous to their commencement.

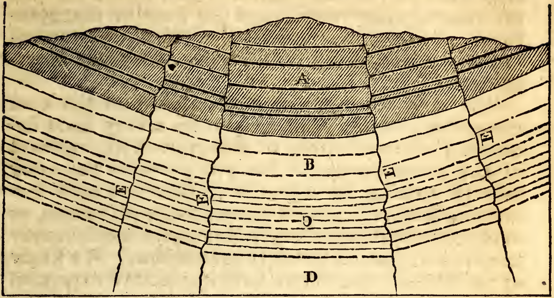
In excavating or boring for wells, we should bear in mind that common springs are produced by the percolation of rain water through porous to impervious beds, where they are stopped, as by clay. When the rock beneath is porous, care should be taken not to penetrate through the clay; for, by so doing, the water will be let out. In this manner it is ascertained that many low grounds and wet, marshy soils may be drained, merely by boring the earth. Among highly inclined and even vertical strata, water may sometimes be obtained at different levels, from the saturation of slate, gneiss, or other beds, to a certain degree pervious to water at such levels, so that if a well be formed in such situations, the water will penetrate into the cavity, and fill it up to the height to which the line of saturation extends. Such is the case in the gneiss rock of the island of New-York, into which Artesian wells have been sunk in various places to the depth of from 100 to 600 feet.

Mining.—Those who have read the preceding part of this treatise must have perceived that the geological facts which have been stated have a direct bearing upon the art of mining. And certainly, judging from the immense amounts which have been expended in fruitless explorations in various parts of the country, for coal, lead, gold, silver, &c., we should say there is no country on the globe where geological knowledge is so much needed as in this. Such is the morbid thirst and eagerness for wealth, that the people are ready to commence their researches on the slightest indications. Companies have been formed and excavations made, in localities where a practical geologist would have said at a glance there was no probability that the substance for which they were searching would be found.

"Certain mineral substances occur, so constantly associated with other particular minerals, that, on finding one, the others may be expected to occur associated with it. Without a knowledge of these associations, and various other facts connected with geology, which require much practical knowledge, attempts at new discoveries, except by mere chance, must be fruitless. The hundreds of excavations in different parts of the country made under the delu-

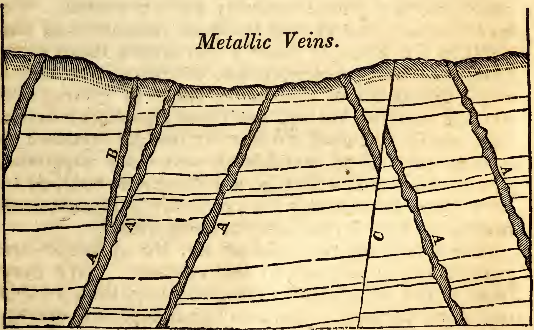
ILLUSTRATIONS OF MINING.

Coal Beds.



Coal basin dislocated by faults. A *Coal Measures.* B *Millstone Grit.* C *Limestone Shale.* D *Mountain Limestone.* E E E E *Faults*

Metallic Veins.



Mineral Veins. A A *Veins.* B *Branch Vein.* C *Dislocation.*

sive hope of reaping a rich reward, attest the zeal for mineral explorations, and the want of that practical and theoretical knowledge which are necessary for the successful prosecution of mining enterprises."*

We have given so full a description of the coal measures, that the reader can form a very good estimate of the probability of discovering this mineral in any given locality. He will perceive the utter folly of seeking for it in the argillaceous slate formation, although highly impregnated with carbon, as at Poughkeepsie and its vicinity, where much money has been expended in such explorations. We know of many instances where individuals have expended their whole fortunes in digging for coal, when the only signs of it were a few pieces of black schorl, contained in primitive rocks. We have observed deep pits and excavations in various parts of the country, made in search of silver and gold, when the only indications were spangles of white isinglass, or talc, or iron pyrites, the nature of which a candle and blowpipe would speedily have revealed. We have already stated that the coal measures do not exist in the State of New-York, unless there have been enormous dislocations, throwing our strata some thousands of feet below those of Pennsylvania and the Ohio Valley; and though geology teaches that metals and coal are not exclusively confined to certain geological epochs, as was once supposed, yet it also teaches that good bituminous coal, fit to be worked extensively for profitable purposes, does not occur out of the carboniferous group.

The following remarks of Mr. De la Beche are particularly applicable to this country: "We may here notice the singular circumstance, that, in this country (England), where so much capital is invested in metalliferous mines and collieries, there should be no national school or college of mines, though

* Prof. L. C. Beck's "Report," &c., 1837.

the great utility of such establishments is amply proved by experience in foreign countries, where, for the most part, the capital thus invested is comparatively trifling. British miners and coal-workers are compelled to pick up their information how they can. If, by good fortune, young men are placed under those who value science, and are aware of the advantages that may be derived from it, they have certainly little reason to complain; but, unfortunately, this is not the lot of the many. A college of mines, properly conducted, would be alike beneficial to those who invest their money in mines and collieries, and those who work them. It could, indeed, be scarcely otherwise than a national benefit."*

It is ardently to be hoped that our government, in carrying into operation the establishment of the national institution at Washington for the "Diffusion of Useful Knowledge," will take this subject into serious consideration.

Such an institution should contain a national museum, for the purpose of showing the application of geology to the useful purposes of life. There might be exhibited the mineral wealth of the country; the most suitable materials for the construction of roads, public works, and buildings; such as are particularly adapted to ornamental purposes, those from which useful metals are extracted; such as illustrate the application of geology to agriculture; the coal measures, arranged, each stratum in its proper place, and all with reference to instruction; and the situations whence they were obtained should be marked on good maps, which, it is

* The suggestion of Mr. De la Beche has been adopted, and a Museum of Economic Geology formed in London, under the department of Woods and Public Works. As the United States already have a geologist employed, it would be well if they had such a museum in which to deposite the specimens he may collect.

to be hoped, may be formed by a trigonometrical survey of the whole Union. This would give employment to an army of civil engineers who are now reposing in idleness, and prove a vast field of industrious employment, the results of which would be alike useful and honourable to the nation.

AGRICULTURE.

The intimate connexion of geology with agriculture must strike the most superficial observer. On this subject, the following remarks of Mr. Bakewell are well worthy of attention: "By a wise provision of the Author of Nature, it is ordained that those rocks which decompose rapidly are those which form the most fertile soils; for the quality of soils depends on the nature of the rocks from which they were formed. Granite and silicious rocks form barren and sandy soils; argillaceous rocks form stiff clay; and calcareous rocks, when mixed with clays, form marl; but, when not covered by other strata, they support a short but nutritious vegetation. For the formation of productive soils, an intermixture of the three earths, clay, sand, and lime, is absolutely necessary. The oxide of iron also appears to be a requisite ingredient. The proportion necessary for the formation of a good soil depends much on the nature of the climate, but more on the quality of the subsoil, and its power of retaining or absorbing moisture. This alone may make a soil barren, which, upon a different subsoil, would be exceedingly productive. When this is the case, either drainage or irrigation offers the only means of permanent improvement." Again he remarks, that, "in proportion as soils possess a due degree of tenacity, and power of retaining or absorbing heat and moisture, the necessity for a supply of manure is diminished, and in some instances the earths are so fortunately combined as to render all supply of artificial manure unnecessary

He who possesses on his estate the three earths, clay, sand, and lime of a good quality, with facilities for drainage or irrigation, has all the materials for permanent improvement; the grand desiderata in agriculture being to render wet lands dry, to supply dry lands with sufficient moisture, to make adhesive soils loose, and loose soils sufficiently adhesive. The intermixture of soils, where one kind of earth is either redundant or deficient, is practised in some countries with great advantage. Part of Lancashire is situated on the red sandstone. This rock, being principally composed of silicious earth and the oxide of iron, forms of itself very unproductive land; but, fortunately, in many situations it contains detached beds of calcareous marl near the surface. By an intermixture of this marl with the soil, it is converted into fertile land, and the necessity for manure is superseded. The effect of a good marl applied liberally to this land, lasts for more than 20 years. In some lands a mixture of light marl, which contains scarcely a trace of calcareous earths, is found of great service. The good effect of this appears to depend on its giving to the sandy soil a sufficient degree of tenacity. The steril and gravelly soils in Wiltshire have been recently rendered productive by mixing them with chalk; the most liberal application of manure having been found ineffective or injurious. In stiff clay soils, where lime is at a great distance, the land might frequently be improved by an intermixture with silicious sand. A proper knowledge of the quality of the subsoil, and the position of the sub-strata, is necessary to ascertain the capability of improvement which land may possess. It may frequently happen, that a valuable stratum of marl or stone, which lies at a great depth in one situation, may rise near the surface in an adjoining part of the estate, and might be procured with little expense When earths are properly intermixed, instances are known of land producing a succession of good crops for many years, without fallowing or manuring. On the summit of Baden Hill, in an exposed and elevated situation, I have seen a luxuri ant crop of barley growing on land that had borne a succession of 20 preceding crops without manuring."*

Such are the views which have generally prevailed of late on the subject of soils, and the effects of a due admixture of the various ingredients composing them. Some writers, however, maintain, that the best possible mixtures do not directly give fertility, but that this depends on the salts or soluble organic matter contained in them; and that a due proportion of sand, clay, and lime forming the soil, favours vegetation, by allowing the air, moisture, and lime rapidly to dissolve organic matter, and yield it readily to the roots of plants. This decomposed organic matter is called *geine* by Berzelius, *humin* by Sprengel and other chemists. It is, however, unimportant in what manner a due proportion of the above elements acts in producing fertility, the *fact itself* being the chief point to which we wish to call attention.

We have stated that Professor Hitchcock has discovered the singular fact, that not one in thirty of the soils of Massachusetts contain any calcareous matter. This accounts for the great benefit generally produced by the application of lime to her soils; for analysis shows that lime forms one of the constituent parts of vegetables. One of the most important benefits ever conferred by geology upon agriculture, is the late discovery of the immense advantages resulting from the application of the *green sand marl* of New-Jersey to sandy soils. We cannot present this matter in a better light than by quoting some passages from a late

* Bakewell's Geology, p. 390.

report of Professor Rogers to the Legislature of New-Jersey. "When we behold," says he, "a luxuriant harvest gathered from fields where the soil originally was nothing but sand, and find it all due to the use of a mineral sparsely disseminated in the sandy beach of the ocean, we must look with exulting admiration upon the benefits upon vegetation conferred by a few scattered granules of this unique and peculiar substance. The small amount of green sand dispersed through the common sand is able, as we behold, to effect immeasurable benefits, in spite of a great predominance of the other material, which we are taught to regard as, by itself, so generally prejudicial to fertility. This ought to exhibit an encouraging picture to those districts not directly within the limits of the marl tract, where some of the strata possess the green substance in sensible proportion. It expands most materially the limits of the territory where marling may be introduced, and points to many beds as fertilizing which would otherwise be deemed wholly inefficacious."* We may lay it down as a general rule, then, that there is no soil which may not be made productive by proper management. For such knowledge, communicated in the most pleasing style, we beg to refer to the work of Judge Buel on Agriculture, which forms one of the series of Harper's School District Library.

* Mr. Rogers states that land which, previous to the discovery of the green sand, sold for $2 50 the acre, is now worth $37 the acre, in consequence of the permanent increase in its value from the marl, as marling costs but $5 per acre, and other manure to produce an equal effect $200

GLOSSARY

OF SOME

GEOLOGICAL TERMS,

CHIEFLY FROM MATHER'S GEOLOGY

A.

Alluvial. The adjective of Alluvium.

Alluvion. A synonyme of Alluvium.

Alluvium. Recent deposites of earth, sand, gravel, mud, stones, peat, shell banks, shell marl, drift sand, &c., resulting from causes now in action. This term is generally applied to those deposites in which water is the principal agent.

Alum rocks. Rocks which, by decomposition, form Alum.

Amorphous. Bodies devoid of regular form.

Amygdaloid. A trap rock which is porous and spongy, with rounded cavities scattered through its mass. Agates and simple minerals are often contained in these cavities.

Anthracite. A species of mineral coal, hard, shining, black, and devoid of bitumen.

Anticlinal. An anticlinal ridge or axis is where the strata along a line dip contrariwise, like the sides of the roof of a house.

Arenaceous. Sandy.

Argillaceous. Clayey.

Augite. A simple mineral of variable colour, from black through green and gray to white. It is a constituent of many volcanic and trappean rocks, and is also found in some of the granitic rocks.

Avalanche. This term is usually applied to masses of ice and snow which have slidden from the summits or sides of mountains. It is now also applied to slides of earth and clay

B.

Basalt. One of the common trap rocks. It is composed of augite and feldspar, is hard, compact, and dark green or black, and has often a regular columnar form. The Palisades of the Hudson show the columnar aspect of trap rocks. The Giant's Causeway is cited as an example of basaltic rocks, and the columnar structure is there very strikingly displayed.

Bitumen. Mineral pitch, which is often seen to ooze from fossil coal when on fire.

Bituminous Shale. A slaty rock, containing bitumen, and which occurs in the coal measures.

Blende. Sulphuret of zinc. A common shining zinc ore.

Bluffs. High banks of earth or rock, with a steep front. The term is generally applied to high banks forming the boundaries of a river, or river alluvions.

Botryoidal. Resembling a bunch of grapes in form.

Boulders. Rocks which have been transported from a distance, and more or less rounded by attrition or the action of the weather. They lie upon the surface or loose in the soil, and generally differ from the underlying rock in the neighbourhood.

Breccia. A rock composed of angular fragments, cemented together by lime or other substances.

C.

Calc Sinter. A German term for depositions of limestone from springs, and waters which contain this mineral in solution.

Calcareous rock. A term synonymous with limestones.

Calcareous Spar. Crystallized carbonate of lime.

Carbon. The combustible element of coal.

Carbonates. Chemical compounds containing carbonic acid, which is composed of oxygen and carbon.

Carbonic Acid. An acid gaseous compound, incapable of supporting combustion, and deleterious to animal life. It is common in caves and wells, and many incautious persons lose their lives in consequence of descending without first ascertaining its presence by letting down a lighted candle. Man cannot live where a candle will not burn freely.

Carboniferous. Coal-bearing rocks. This term has been applied to a formation belonging to an ancient group of secondary rocks which contains coal. The term is now used in a more enlarged sense, and may be applied to any rocks containing coal.

Chert. A silicious mineral, approaching to chalcedony, flint, and hornstone. It is usually found in limestone.

Chlorite. A soft green scaly mineral, slightly unctuous.

Chloritic Slate. Slate containing chlorite.

Clinkstone. A slaty feldspathic or basaltic rock, which is sonorous when struck.

Cleavage. The separation of the laminæ of rocks and minerals in certain constant directions. They are not always parallel to the planes of stratification, but are often mistaken for them.

Coal formation. Coal measures. These terms are considered synomynous, and refer to the great deposite of coal in the older secondary rocks, which has been called the "independent coal formation." There are, however, deposites of carbonaceous matter in all the geological periods, and several of them might also be called coal formations.

Conformable. When strata are arranged parallel to each other, like the leaves of a book, they are said to be conformable. Other strata lying across the edges of these may be conformable among themselves, but *unconformable* to the first set of strata.

Conglomerate, or Pudding-stone. Rocks composed of rounded masses, pebbles and gravel cemented together by a silicious, calcareous, or argillaceous cement.

Cretaceous. Belonging to the chalk formation.

Crop out and out crop. Terms employed by geologists and mining engineers to express the emergence of rock, in place, on the surface of the earth at the locality where it is said to crop out.

Crystalline. An assemblage of imperfectly defined crystals, like loaf sugar and common white marble.

D.

Delta. Alluvial land formed at the mouths of rivers.

Denudation. A term used to express the bare state of the rocks over which currents of water have formerly swept, and laid the rocks bare, or excavated them to form valleys of denudation.

Deoxidize. To separate oxygen from a body.

Dikes. A kind of vein intersecting the strata, and usually filled with some unstratified igneous rock, such as granite, trap, or lava. These materials are supposed to have been injected in a melted state into great rents or fissures in the rocks.

Diluvium and *Diluvion.* Deposites of bowlders, pebbles, and gravel, which many geologists have supposed were produced by a diluvial wave or deluge sweeping over the surface of the earth.

Dip. Where strata are not horizontal, the direction in which their planes sink or plunge is called the direction of the dip, and the angle of inclination the angle of dip.

Dolomite. A magnesian limestone belonging to the primary class. It is usually granular in its structure, and of a friable texture.

Dunes. Sand raised into hills and drifts by the wind.

E.

Earth's Crust. The superficial parts of our planet which are accessible to human observation.

Eocene. The strata deposited during the oldest of the tertiary epochs, as, for example, the Paris Basin.

Estuaries. Inlets of the sea into the land. The tides and fresh-water streams mingle and flow into them. They include not only the portion of the sea adjacent to the mouths of rivers, but extend to the limit of tide-water on these streams.

Exuvia. In geology, fossil remains.

F.

Fault. A dislocation of strata, at which the layers on one side of a dike or fissure have slidden past the corresponding ones on the other. These dislocations are often accompanied by a dike. They vary from a few lines to several hundred feet.

Feldspar. One of the simple minerals, and, next to quartz, one of the most abundant in nature.

Ferruginous. Containing iron.

Fluviatile. Belonging to a river.

Formation. A group of rocks which were formed during a particular period, or which are referred to a common origin.

Fossils. The remains of animals and plants found buried in the earth or enclosed in rocks. Some of these are but slightly changed, others are petrified, and the organic replaced by mineral matter; some have decayed and left the impression of the bodies, while others have been formed by mineral matter deposited in the cavities left by the decay of the organic body. These last are called *casts*. The term petrifaction is applied to those causes in which organic matter has been replaced by mineral substances. The form and structure of the original body both remain. In casts the exterior form alone is preserved. Fossils are also called organic remains.

Fossiliferous. Containing organic remains.

G.

Galena. An ore of lead, composed of lead and sulphur.

Garnet. A simple mineral, which is usually red and crystallized. It is abundant in most primitive rocks.

Gneiss. A stratified primary rock, composed of the same materials as granite, but the mica is distributed in parallel layers, which give it a striped aspect.

Geology. A science which has for its object to investigate the structure of the earth, the materials of which it is composed, the manner in which these are arranged with regard to each other; and it considers the action of all natural causes in producing changes, such as the effects of frost, rain, floods, tides, currents, winds, earthquakes, and volcanoes.

Economical Geology refers to the application of geological facts and observations to the useful purposes of civilized life.

Granite. An unstratified rock, composed generally of quartz, feldspar, and mica, and it is usually associated with the oldest of the stratified rocks.

Graywacke Grauwacke. A group of strata in the transition of rocks; but the term has been so indefinitely applied, that other names will probably be substituted.

Greenstone. A trap rock, composed of hornblende and feldspar.

Grit. A coarse-grained sandstone.

Gypsum. A mineral, composed of sulphuric acid and lime, and extensively used as a stimulant manure, and for making stucco and plaster casts, &c. It is also called Plaster of Paris.

H.

Hornblende. A mineral of a dark green or black colour, and which is a constituent part of greenstone.

Hornstone. A silicious mineral, approaching to flint in its characters.

I.

In Situ. In their original position where they were formed.

L.

Laminæ. The thin layers into which strata are divided, but to which they are not always parallel.

Lacustrine. Belonging to a lake. Depositions formed in ancient as well as modern lakes, are called lacustrine deposites.

Landslip. It is the removal of a portion of land down an inclined surface. It is in consequence of the presence of water beneath, which either washes away the support of the superincumbent mass, or so saturates the materials that they become a slippery paste.

Line of Bearing, is the direction of the intersection of the planes of the strata with the plane of the horizon.

Lignite. Wood naturally carbonized and converted into a kind of coal in the earth.

Littoral. Belonging to the shore.

Loam. A mixture of sand and clay.

M.

Mural Escarpment. A rocky cliff, with a face nearly vertical like a wall.

Mammillary. A surface studded with smooth small segments of spheres like the swell of the breasts.

Mammoth An extinct species of the elephant.

Marl. By this term an argillaceous carbonate of lime is usually implied. By custom, its signification is much more extended, and means mineral substances, which act as stimulating or fertilizing manures. There are clay marls, shell marls, and various others.

Mastodon. A genus of extinct fossil animals allied to the elephant. They are so called from the form of the grinders, which have their surfaces covered with conical mammillary crests.

Matrix. The mineral mass in which a simple mineral is imbedded is called its *matrix* or *gangue.*

Megatherium. A fossil extinct; a quadruped resembling a gigantic sloth.

Mechanical origin, Rocks of.—Rocks composed of sand, pebbles, or fragments, are so called, to distinguish them from those of a uniform crystalline texture, which are of chemical origin.

Mica. A simple mineral, having a shining silvery surface, and capable of being split into very thin elastic leaves or scales. The brilliant scales in granite and gneiss are mica.

Mica Slate. One of the stratified rocks belonging to the primary class. It is generally fissile, and is characterized by being composed of mica and quartz, of which the former either predominates, or is disposed in layers, so that its flat surfaces give it the appearance of predominating.

Miocene. One of the deposites of the tertiary epoch. It is more recent than the *eocene,* and older than the pliocene.

Mollusca. Molluscous animals. "Animals, such as shell fish, which, being devoid of bones, have soft bodies."

Mountain Limestone. "A series of limestone strata, of which the geological position is immediately below the coal measures, and with which they also sometimes alternate."

Muriate of Soda. Common salt.

N.

Naptha. A fluid volatile inflammable mineral, which is common in volcanic districts, and in the vicinity of the Salt Springs of the United States.

New Red Sandstone. "A series of sandy and argillaceous, and often calcareous strata, the prevailing colour of which is brick red, but containing portions which are greenish gray. These occur often in spots and stripes, so that the series has sometimes been called the variegated sandstone. The European, so called, lies in a geological position immediately above the coal measures."

Nodule. A rounded, irregular shaped lump or mass.

O.

Old Red Sandstone. "A stratified rock belonging to the carboniferous group of Europe."

Oolite. "A limestone, so named, because it is composed of rounded particles like the roe or eggs of fish. The name is also applied to a large group of strata characterized by peculiar fossils."

Organic Remains. See *Fossils.*

Orthoceratite. The remains of an extinct genus of molluscous animals, called Cephalopoda. The orthoceratites are long, straight, conical-chambered shells.

Out-crop. See *Crop-out.*

Outliers. Hills or ranges of rock strata, occurring at some distance from the general mass of the formations to which they belong. Many of these have been caused by denudation, having removed parts of the strata which once connected the outliers with the main mass of the formation.

Oxide. A combination of oxygen with another body. The term is usually limited to such combinations as do not present active acid or alkaline properties.

P.

Palaeontology. A science which treats of fossil remains.

Pisolite. A calcareous mineral, composed of rounded concretions like pease.

Pliocene. The upper or more recent tertiary strata. This group of strata is divided into the older and newer pliocene rocks.

Petroleum. A liquid mineral pitch. It is common in the region of salt springs in the United States.

Porphyry. A term applied to every species of unstratified rock, in which detached crystals of feldspar are diffused through a compact base of other mineral composition.

Productus. An extinct genus of fossil bivalve shells.

Plastic Clay. One of the beds of the eocene period. The plastic clay formation is mostly composed of sands with associate beds of clay.

Pudding-stone. See *Conglomerate.*

Pyrites. A mineral composed of sulphur and iron. It is usually of a brass yellow, brilliant, often crystallized, and frequently mistaken for gold.

Q.

Quartz. A simple mineral, composed of silex. Rock crystal is an example of this mineral.

R.

Rock. All mineral beds, whether of sand, clay, or firmly aggregated masses, are called rocks.

S.

Sandstone. A rock composed of aggregated grains of sand.

Saurians. Animals belonging to the lizard tribe.

Schist. Slate.

Seams. "Thin layers which separate strata of greater magnitude."

Secondary Strata. "An extensive series of the stratified rocks, which compose the crust of the globe, with certain characters in common, which distinguish them from another series below them, called primary, and another above them, called tertiary."

Sedimentary Rocks are those which have been formed by their materials having been thrown down from a state of suspension or solution in water.

Selenite. Crystallized gypsum.

Septaria. Flattened balls of stone, which have been more or less cracked in different directions, and cemented together by mineral matter which fills the fissures.

Serpentine. A rock composed principally of hydrated silicate of magnesia. It is generally an unstratified rock.

Shale. An indurated slaty clay, which is very fissile.

Shell Marl—Fresh-water Shell Marl. A deposite of fresh-water shells, which have disintegrated into a gray or white pulverulent mass.

Shingle. The loose, water-worn gravel and pebbles on shores and coasts.

Silex. The name of one of the pure earths which is the base of flint, quartz, and most sands and sandstones.

Silt. "The more comminuted sand, clay, and earth which is transported by running water."

Simple Minerals are composed of a single mineral substance. Rocks are generally aggregates of several simple minerals cemented together.

Slate. A rock dividing into thin layers.

Stalactite. Concreted carbonate of lime, hanging from the roofs of caves, and like icicles in form.

Stalagmites. Crusts and irregular-shaped masses of concreted carbonate of lime, formed on the floors of caves by deposites from the dripping of water.

Stratification. An arrangement of rocks in strata.

Strata. Layers of rock parallel to each other.

Stratum. A layer of rocks; one of the strata.

Strike. The direction in which the edges of strata crop out. It is synonymous with *line of bearing*.

Syenite and *Sienite.* A granite rock, in which hornblende replaces the mica, or forms an ingredient.

Synclinal line and *Synclinal axis.* When the strata dip downward in opposite directions, like the sides of a gutter.

T.

Talus. In geology, a sloping heap of broken rocks and stones at the foot of many cliffs.

Tertiary Strata. "A series of sedimentary rocks, with characters which distinguish them from two other great series of strata, the secondary and primary, which lie beneath them."

Testacea. "Molluscous animals, having a shelly covering."

Tepid. Warm.

Thermal. Hot.

Thin out. Strata which diminish in thickness until they disappear are said to *thin out.*

Trap—Trappean Rocks. Ancient volcanic rocks, composed of feldspar, hornblende, and augite. Basalt, greenstone, amygdaloid, and dolerite, are trap rocks.

Travertin. "A concretionary limestone, hard and semi-crystalline, deposited from the water of springs."

Tufa Calcareous. "A porous rock, deposited by calcareous waters on exposure to air, and usually containing portions of plants and other organic substances incrusted with carbonate of lime."

Tufaceous. A texture of rock like that of tuff.

Tuff or *Tufa.* "An Italian name for a volcanic rock of an earthy texture."

U.

Unconformable. See *Conformable.*

V

Veins. Cracks and fissures in rocks filled with stony or metallic matter. Most of the ores are obtained from metallic veins.

Z.

Zoophytes. Coral sponges and other aquatic animals allied to them.

THE END.