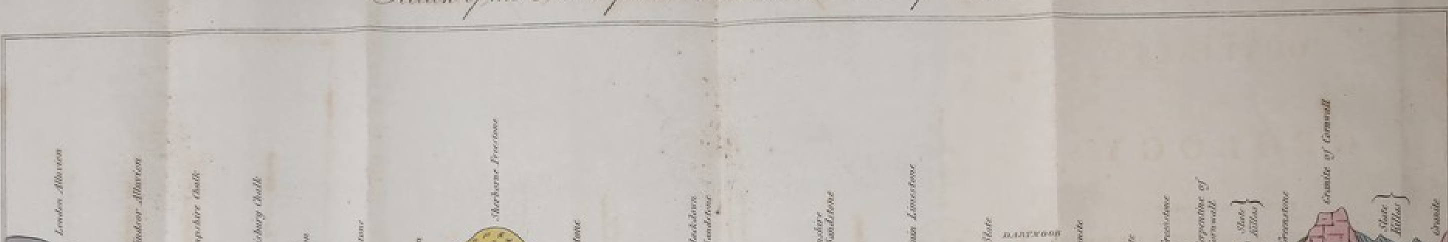
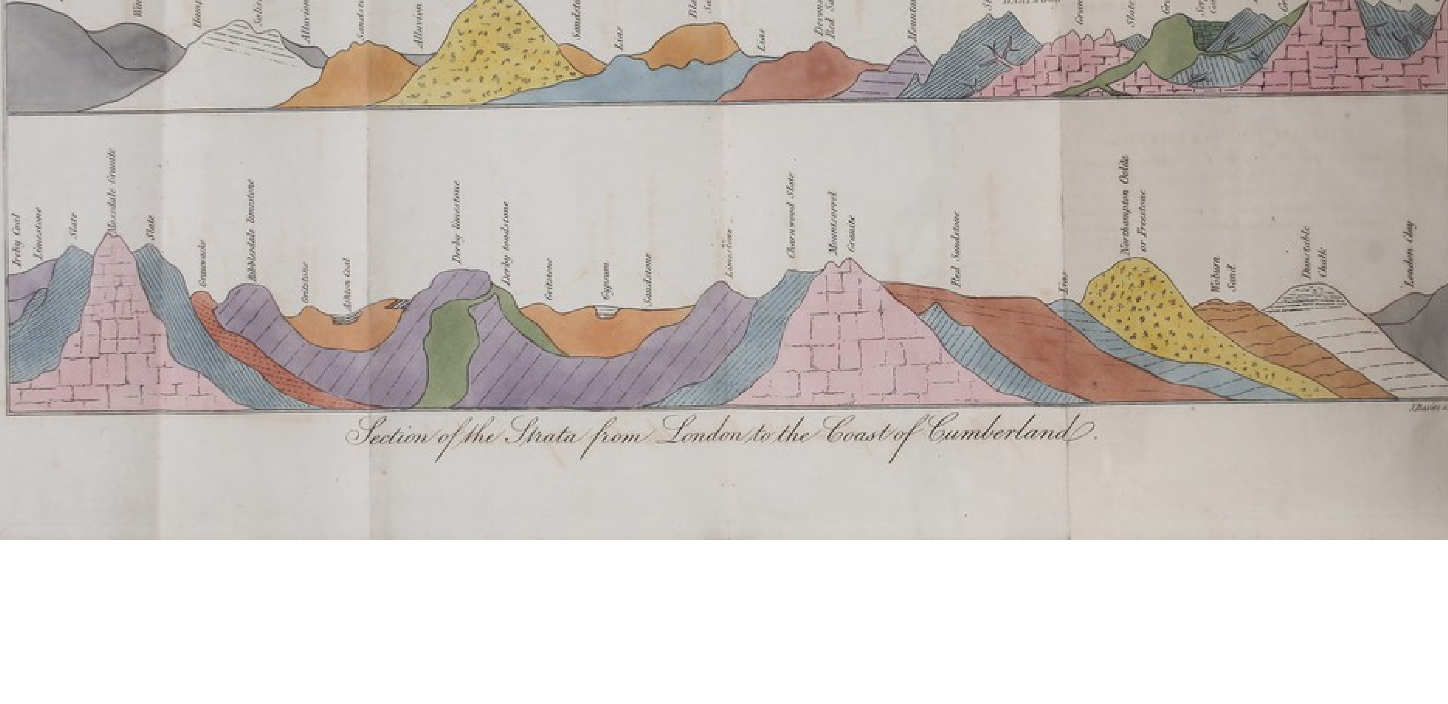

NIL SISTERE CONTRA

Section of the Strata from London to the Coast of Cornwall.





Section of the Strata from London to the Coast of Cumberland.

OUTLINES

OF

GEOLOGY;

BEING THE SUBSTANCE OF

A COURSE OF LECTURES DELIVERED IN THE THEATRE
OF THE ROYAL INSTITUTION

IN THE YEAR 1816.

BY

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THE

FOLLOWING PAGES ARE DEDICATED

TO THE

PRESIDENT AND MEMBERS

OF THE

ROYAL INSTITUTION OF GREAT BRITAIN.

BY

THEIR FAITHFUL SERVANT,

THE AUTHOR.

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EXPLANATION OF THE PLATE.

The annexed Plate is intended to give a general idea of the succession of alluvial, secondary, transition, and primary strata, in England.

The upper section commences with the blue clay of London, and proceeding westward through the counties of Berkshire, Hampshire, Wiltshire, Dorsetshire, and Devonshire, terminates at the Land's End in Cornwall. The rocks presented in this line are chalk, sandstone, oolite or free stone, lias or argillaceous and magnesian limestone, red sandstone, mountain limestone or secondary marble, slate, greenstone, serpentine, and granite. The latter frequently penetrates the slaty stratain veins, and is itself pervaded by greenstone. See page 46, &c.

The second section commences with the coal strata, and limestone resting upon slate and granite in Cumberland, and thence proceeds towards the metropolis by Yorkshire, Derbyshire, Leicestershire, Northamptonshire, Bedfordshire and Hertfordshire. The passage is here exhibited, from the primary rocks of Cumberland, to the secondary hills of the southern counties. It shews the grit and sandstone containing coal, which lies upon the mountain limestone of Derbyshire, which rock is singularly penetrated by toadstone. In Leicestershire slate and granite again occur, and are succeeded by red sandstone, lias, oolite, sandstone, and chalk, upon which the blue clay of Middlesex is deposited, and of which the valley of the Thames in that county, principally consists. It is obvious, that the relative heights and extents of the different rocks are scarcely intended to be exhibited by these sections; their chief object is to shew their relative positions.

LECTURES ON GEOLOGY.

LECTURE I.

Introductory — General Remarks on the Objects of Geological Science.—Sketch of the Theories of Burnet, Woodward, Leibnitz, Whiston, Whitehurst, Buffon—Wernerian and Huttonian Theories.

It is usual, at the opening of a Course of Lectures upon any branch of science or art, to define its objects, and briefly expose the importance, usefulness, or interest, which it possesses. Geology embraces so many topics of discussion, its range is so extensive, and the meanings given to the term are so various and opposite, as to throw no inconsiderable difficulties in his way who would enumerate and expound them. Persons have been called Geologists who, gifted with prolific imaginations, have indulged in fanciful speculation concerning a former order of things, and have reared hypotheses respecting the origin of our planet upon foundations so flimsy and unsubstantial, as to deserve no other appellation than flighty excursions of a poetic mind. Others, by careful, diligent, and extended observations of the present state of the earth's surface, have endeavoured, in the path of induction, to trace the nature of the agents which have once been active, to ascertain how far they are now operating, and to anticipate the results of their continuance. If they frame theories, they do so upon the results of actual research; if they indulge in speculation, they assign to it its proper place. These are really Geologists, and their aim is, not to imagine or suppose, but to *discover* the nature of all changes of the earth's surface and interior, and thence to arrive at the laws that regulate them. As the great object of the lecturer on Geology should be to draw the attention of his audience to facts and ocular evidence, rather than to opinions and disputative inquiry, we shall principally cultivate the acquaintance of Geologists of the latter class; but it will also be right to give a slight sketch of the mode of inquiry taken up by their predecessors; for although it be true, that they have commonly dealt rather in words than in things, and are entertaining rather than instructive, we shall find some among them whose incongruities are duly blended with ingenuity, and whose pious and benevolent intentions must be weighed against their incorrect and hasty conclusions.

Geology, as a branch of inductive science, is of very modern date; for though the attention of men has long been turned to a theory of the earth, the formation of such a theory is incompatible with any but an advanced state of physical knowledge. There appear indeed few studies of more difficulty; none in which the subject is more complex; appearances so diversified and scattered; and where the causes that have operated are so remote from the sphere of ordinary observation.

The first writer, whose name merits

notice, is Thomas Burnet,* who may justly be said to have adorned the latter half of the seventeenth century. And though it be true that his pen has rather recorded the sallies of a vivid imagination, than the inferences of sober argument, he will still be read with some profit, though certainly with more pleasure, even in these times. The objection to Burnet and his contemporaries, and immediate successors, is, that they fancifully go back to the chaotic state of the earth, and after enlarging, embellishing, and obscuring the Mosaic history, they pretend to have illustrated and proved it. Accordingly, Burnet, in his Sacred Theory of the Earth, begins with the separation of elements from a fluid mass. The heaviest particles sank, and formed a nucleus, and water and air took their respective stations: upon the water, however, the air afterwards deposited a rich unctuous crust, which begat vege-

* The Sacred Theory of the Earth, containing an Account of the Original of the Earth, and of all the general changes which it hath already undergone, or is to undergo, till the consummation of all things. (8vo.) London, 1726.

tation, and a beautiful verdure clothed the whole. There were no mountains, no seas, no protuberances or inequalities; and the equator being coincident with the plane of the ecliptic, all the charms of spring were perpetual. This state of things, however, did not thus continue for many centuries; for the sun caused large cracks and fissures in the exterior, which by gradual increase extended to the great aqueous abyss; the waters rose higher and higher, the surface was utterly broken up and destroyed, and an universal deluge took place: at length dry land began again to appear, owing to a gradual subsidence of the waters which retired into caverns and crevices originally existing in the nucleus, or formed by the disruption of the crust: upon the increasing dry land, vegetation began again to exist, and our present islands and continents were formed, while the sea still occupies in parts its original bed.

I do not recite the minutiæ of Burnet's romance, because they may be had from books; the great object and use of public lectures being, to produce that which cannot be derived from such sources, by addressing the eye rather than the ear; or so to condense what can, as to present in a few pages the essence of many volumes. Nor shall I now, or upon any other occasions, meddle with the adjustments of these and like speculations to the records of Holy Writ. If, in the laborious path of experimental investigation, we are occasionally rewarded with the discovery of some new adaptations of causes and effects, which had before escaped notice, but which demonstrate how all things on earth are made to work together for good; the discovery strengthens our faith, and calls forth the best feelings of which the human heart is susceptible; but we must not presume to submit the aptitude of nature's arrangement to the feeble powers of human decision, to doubt her perfection because our imbecile capacities cannot attain its comprehension, or to found our proofs of the existence or even of the attributes of the Deity, upon the limited, imperfect, or ideal conception of the excellence of nature's works, of which the human understanding is capable. Although Burnet's Theory, as he calls it, was a mere hypothetical product of the imagination, unsupported by a single fact, or by the slightest observed phenomenon, it excited much admiration and some discussion, and was criticised with much acrimony and some ability;* more especially by Keill, of Oxford.† His style is in general terse and elegant, though it occasionally degenerates into the predominant pomposity of the period at which he wrote. He was the translator of his own work from Latin into English. Two brief samples from the latter will be sufficient for elucidation. After

* By Dr. Herbert Crofte, in 1685; by Dr. Beaumont, in 1693, and by Erasmus Warren.

† An Examination of Dr. Burnet's Theory, &c. by J. Keill, A.M. of Baliol Coll. Oxon. Second Edition, 1734, 8vo. "He (Burnet) begins his discourse with a saying of an old heathen, that philosophy is the greatest gift that ever God bestowed on man; but it is plain to any who will be at the pains to read his book, that God has thought fit to bestow but very little of that great gift upon him, and that the world may not say this is ill nature, I will give them a taste of his philosophy," &c. This is the general style of the "Examination."

observing that the obscurity and remoteness of his subject has by some been used as an argument against undertaking it. "This," says he, "does but add to the pleasure of the contest where there are hopes of victory, and success more than recompenses all the pains. No joy is more grateful to man than the discovery of truth, especially where it is hard to come by. Every man has a delight suited to his genius, and as there is pleasure in the right exercise of any faculty, so especially in that of right reasoning, which is still the greater by how much the consequences are more clear, and the chains of them more long. There is no chace so pleasant, methinks, as to drive a thought from one end of the world to the other, and never to lose sight of it till it falls into eternity, where all things are lost, as to our knowledge."

The following passage from Burnet's work has been highly eulogised by Steele,* and certainly it merits praise; it is a funeral

* Spectator, No. 146.

Attached to the English edition of Burnet's work, above referred to, is an "Ode to the Author by Mr.

oration over the globe: "Let us now," says he, "reflect on the transient glory of the earth; how, by the force of one element breaking loose on the rest, all the beauties of nature, each work of art, and every labour of man, are reduced to nothing; all that once seemed admirable, is now obliterated; all that was great and magnificent, has vanished; and another form and face of things, plain, simple, and uniform, overspreads the earth. Where are now the empires of the world? where the imperial cities, the pillars, trophies, and monuments of glory? what remains, what impressions or distinctions do you now behold? what is become of Rome, the great city; of eternal Rome, the empress of the world, whose foundations were so deep, whose palaces were so sumptuous?—her hour is come, she is wiped from the face of the earth, and buried in everlasting

Addison," in the ordinary fulsome style of that period. The following stanza is a specimen:

Jamque alta Cœli mœnia corruunt,
Et vestra tandem pagina, (proh nefas!)
Burnette, vestra augebit ignes,
Heu socio peritura Mundo.

oblivion. But not the cities only, and the works of men's hands, but the hills and mountains, and rocks of the earth are melted as wax before the sun, and their place is no-where found ; all have vanished and dropped away, like the snow that once rested upon their summits.*"

It is impossible to read this quotation without being reminded of one of the most beautiful passages in the "Art of Preserving Health," where Armstrong has happily introduced very similar ideas.

What does not fade ? the tower that long had stood
The crash of thunder and the warring winds,
Shook by the slow, but sure destroyer, time,
Now hangs in doubtful ruins o'er its base ;
And flinty pyramids, and walls of brass
Descend ; the Babylonian spires are sunk ;
Achaia, Rome, and Egypt moulder down.
Time shakes the stable tyranny of thrones,
And tottering empires rush by their own weight.
This huge rotundity we tread grows old,
The sun himself, shall die, and ancient night
Again involve the desolate abyss.†

* Burnet's Theory, Vol. 2. p. 25.

† Art of Preserving Health, Book. 18.

I might select many more beauties from the Sacred Theory of the Earth. The passages I have quoted, however, shew the general strain of the author, and it would be irrelevant amusement to pursue them.

A very different reasoner from Burnet, was Woodward; he was nothing of a poet, and not much of a philosopher; he pretends to be a matter of fact man; but having collected a few observations respecting the contents of strata, hastily proceeded to the erection of a Theory; "to build a ship," as Lord Bacon says, "with materials insufficient for the rowing pins of a boat." —Woodward observed the existence of fossil shells, and remarked, that the lower strata of the earth's surface were generally harder than the upper, which were of more light and pulverulent materials; whence he concluded, that at the period of the deluge, the earth had acquired a new crust deposited upon it by the waters, in the succession of the specific gravity of the materials; the heaviest, coarsest, and hardest bodies forming what to us seem a nucleus, covered by finer and lighter deposits.*

About this time Leibnitz published his "Protogæa;"† he supposes the earth to have been in a state of combustion for many ages, and at length to have gone out for want of fuel. A glassy crust was thus formed, which gave rise to sand and gravel; other kinds of earth resulted from sand and salt; and as the globe cooled, the water which had before been kept in the state of steam, assumed fluidity, and falling to the earth, produced the ocean. The par-

* Woodward applied the geological observations he had made in England to other countries. "I was abundantly assured that the circumstances of these things in remoter countries were much the same with those of ours here; that the stone and other terrestrial matter in France, Flanders, Holland, Spain, Italy, Germany, Denmark, Norway, and Sweden was distinguished into layers as it is in England, &c. &c. To be short, I got intelligence that these things were the same in Africa, Arabia, Persia, and other Asiatic provinces; in America, &c." See "An Essay towards a natural History of the Earth and terrestrial Bodies." By John Woodward, M. D. &c. London, 1702.

† Leibnitzii Opera Omnia. Genevæ, 1768. Vol. 2. p. 199.

ticulars of these notions are, of course, not worth reciting.

Whiston,* having blended the follies of Burnet, Woodward, and Leibnitz, endeavours to conceal his imbecility under the lion's skin of mathematical calculation; and taking many things for granted, of which there is not the most distant probability, leaves us bewildered and perplexed: he is neither plausible nor amusing, and is best known as having called forth the libellous witticism of Swift. But there was a contemporary of Whiston, whose works deserve more attention; John Whitehurst,† a native of Congleton in Cheshire: he passed much of his time in Derbyshire, and investigated, with considerable ability, the stratification of that rich and interesting

* New Theory of the Earth, &c. by William Whiston, M. A. 4th Edition, London, 1725.

† The works of John Whitehurst, F. R. S. London 1792. "It is my intention, (says Whitehurst, in his preface to the Inquiry into the original state and formation of the Earth,) to trace appearances in nature from causes truly existent; and to enquire after those laws by which the Creator chose to form the world, not those by which he might have formed it, had he so pleased."

county; "hoping," as he expresses it, "to obtain such knowledge of subterraneous geography, as might be subservient to the purposes of life, by exposing new treasures which are concealed in the lower regions.* In his inquiry into the original state and formation of the earth, he has assiduously collected facts, among which his account of the strata of Derbyshire retains much value, at the present day, though repeated investigations have since been made, with all the advantages of modern improvements. And as to his theoretical views, I think it is scarcely going too far to say, they are the best extant; for, unlike later geologists, he first collected facts and then constructed his theories; and those, if any now there be, who are unbiassed by speculative doctrine, and really think for

* Whitehurst particularly notices the similarity of succession in the strata of England, and in his description of Derbyshire, he mentions the resemblance of the Toadstone to Lava; and infers, from its appearance, situation, and effects, that it must have issued from below in an ignited state, that it must have been projected with great violence amidst the superincumbent strata, and that their displacements and irregularities are the consequence.

themselves, will consequently accede to by far the greater number of his leading positions.

But no one has proceeded to the forming of a theory of the earth with the pomp and circumstance of Buffon.* It merits attention, not on account of its accordance with present appearances, or as affording plausible solutions of observed phenomena, but from the eloquence with which it is adorned, the extent of information it displays, and the popularity it derived from these sources.

He supposes the planets in general to have been struck off from the sun by a comet; that they consisted of fluid matter, and thence assumed a spherical form; and that by the union of centrifugal and centripetal forces they are restrained in their present orbits. The earth gradually cooled, and the circumambient vapours condensed upon its surface, while sulphureous, saline, and other matters penetrated its cracks and fissures, and formed veins

* Histoire et Théorie de la Terre et des Epoques de la Nature. 4 Vol. 8vo. Paris, 1800.

of metallic and mineral products. The scorified or pumice-like surface of the earth, acted upon by water, produced clay, mud, and loose soils, and the atmosphere was constituted of subtile effluviæ floating above all the more ponderous materials. Then the sun, and winds, and tides, and the earth's motion, and other causes, became effective in producing new changes. The waters were much elevated in the equatorial regions, and mud, gravel, and fragments were transported thither from the poles ; hence, says Buffon, the highest mountains lie between the tropics, the lowest towards the poles ; and hence the infinity of islands which stud the tropical seas. The globe's surface, once even and regular, became now rough and irregular ; excavations were formed in one part, and land was elevated in another ; and during a period of ages, the fragments of the original materials, the shells of various fish, and different other exuviæ, were ground up by the ocean and produced calcareous strata, and other lowland depositions. These relics of marine animals we find at such heights above the present level of the sea, as to render it more than probable, that the ocean once entirely overwhelmed the earth.

Of the phenomena I have hinted at, Buffon takes particular and extended notice, and draws from them a series of curious and minute conclusions; not however satisfactory or logical, inasmuch, as many of the data they are founded upon, are imaginary, not real. Every one who now contemplates the earth's surface, must trace upon it marks of the most dire and unsparing revolutions, which, from the present order of things, it appears impossible should re-occur, except by the united and continuous agency of the most active powers of destruction. This, says Buffon, arose from the soft state of the former crust of the earth, and those causes, now imbecile and slow in their operation, were then more effectually exerted, and results were obtained in a few years, for which centuries would now be insufficient.

This amusing theorist next proceeds to contemplate the production of rivers, which he regards as having cut their own way to the ocean, as gradually wearing down the mountainous lands, filling up vallies, and choaking their exits into the ocean by the transportation of finely divided materials. Thus every thing is slowly returning to its former state; the mountains will be leveled, the vallies heightened, excavations filled up, and the ocean will again cover the earth. I shall not enter into the various confutations of these speculative notions, nor dwell upon many modern theories to which they have given rise. Pallas, Kirwan, De Luc, and others, have animadverted upon, but can scarcely be said to have improved, Buffon's hypothesis: and as we set out with granting it to be the mere fabric of imagination, it would be folly to submit it to the solemnity of philosophic criticism.

Many other theories of the earth I pass over in silence, as containing nothing not to be met with in some of the already mentioned Cosmogonists. The authors have sometimes clothed their fictions in new dresses, or presented them under new forms, but if we remove the mask, Burnet or Buffon are instantly recognized. Thus, in pretending to advance learning, they have rather obstructed it, and have accumulated hypotheses without enriching science. They deserve that censure thrown upon certain writers by Dr. Johnson, who calls them the persecutors of students and the thieves of time. Such at least I have found them.

There are other geological writers who have accumulated many interesting facts, and whose insulated observations are truly curious and valuable; but their general hypotheses are of so chimerical a cast, as rather to resemble Eastern allegories than European philosophy; they defy all criticism, and therefore lie out of our present track, which now leads us to review the prevailing theories of the present day. These are the inventions of Professor Werner of Freyburgh,* and Dr. Hutton of Edinburgh†, each of whom has been ably supported and elucidated by the proofs, illustra-

* A comparative view of the Huttonian and Neptunian Systems of Geology, in answer to the "Illustrations," by Professor Playfair. Edinburgh, 1802.

† Theory of the Earth, by James Hutton, M. D. F.R.S. Edinburgh 1795. 2 Vol. 8vo.

tions, and comparative views of acute and eloquent controversialists;* and two sects have been formed, under the appellation of Wernerians and Huttonians. The disputes and differences of these contending geologists would now be prematurely noticed, but, in the progress of our inquiries, it will furnish profit and amusement to stand apart and quietly view their skirmishes. They each profess to proceed, as rigidly as the subject allows, in the path of induction, to reject mere hypothesis, and raise their theories upon accumulated facts; and yet they arrive at conclusions diametrically opposite; upon which a clever writer remarks, "that among all the wonders geology presents to our view, the confidence of the theorists is by far the most unaccountable."

The first principle of the Wernerian Theory assumes, that our globe was once covered with a sort of chaotic compost, holding either in solution or suspension the various rocks and strata which now present

* Illustrations of the Huttonian Theory of the Earth, by John Playfair, F. R. S. &c. Edinburgh, 1802.

themselves as its exterior crust. From some unexplained cause, this fluid began first to deposit those bodies which it held in chemical solution, and thus a variety of crystallized rocks were formed. In these we find no vegetable or animal remains, nor even any rounded pebbles; but in the strata which lie upon the crystalline, or first deposits, shells and fragments occasionally occur: these therefore have been termed *transition strata*; and it is imagined that the peopling of the ocean commenced about this period. The waters upon the earth began now more rapidly to subside, and finely divided particles, chiefly resulting from disintegration of the first formations, were its chief contents; these were deposited upon the transition rocks chiefly in horizontal layers. They abound in organic remains, and are termed by Werner, *Floetz*, or *Secondary rocks*.

It is now conceived that the exposure of the *primitive*, *transition*, and *secondary* rocks to the agencies of wind and weather, and to the turbulent state of the remaining ocean, produced inequalites of surface, and that the water retreated into lowlands and vallies, where a further deposition took place, constituting clay, gravel, and other *alluvial* formations.

There are also certain substances which, instead of being found in regularly alternating layers over the earth, are met with in very limited and occasional patches. Rock salt, coal, basalt, and some other bodies are of this character, and Werner has called them *subordinate* formations. Lastly, subterraneous fires have sometimes given birth to peculiar and very limited products; and these are called *volcanic* rocks. Such is Werner's account of the production of rocks, which he arranges under the terms *primary*, *transition*, *secondary*, *alluvial*, *subordinate*, and *volcanic formations*.

A number of nice distinctions and accurate minutiæ of description attend this theory, which we cannot notice in this bird's-eye view, but of which the merits will not be forgotten hereafter.

If we examine the stratification of our globe, we shall doubtless find that certain substances do occur in a certain order of arrangement, and that they appear to have been successively deposited one upon the other in the manner Werner would have us believe. He, therefore, and his disciples have perhaps given a satisfactory account of their own country; but when we examine other parts of the earth's surface, so many incongruities are discovered, and so much is at variance with their leading doctrines, that we are obliged to give them up in favour of views more generally applicable. So that the Neptunian Theory, as this has been called, though ingenious, is not infallible; and though we must allow its author the merit of some originality, and a great deal of diligence, we must not bestow that unalloyed praise which his admirers call for, or join in the unqualified encomium of one of his best expositors, who speaks as follows:* "This great Geognost," says he, meaning Geologist, "after many years of the most arduous investigation, conducted with an

* Vide Jameson's System of Mineralogy.—Introduction, page xxii.

accuracy and acuteness of which we have few examples, discovered the manner in which the crust of the earth is constructed. Having made this great discovery, he, after deep reflection, and in conformity with the strictest rules of induction, drew most interesting conclusions as to the manner in which the solid mass of the earth may have been formed. It is that splendid specimen of investigation, the most perfect of its kind ever presented to the world, which I shall give an account of in the volume of my work which treats of Geognosie ;" meaning geology. Now really, this deification is more than Werner merits.

Dr. Hutton gives a very different account of the present order of things. Looking upon the face of nature, he observes every thing in a state of decay; and as she has obviously provided for the regeneration of animal and vegetable tribes, so the philosophic mind will descry in this apparent destruction of the earth's surface, the real source of its renovation. The lofty mountains exposed to the action of the varying temperature of the atmosphere, and the waters of the clouds, are by slow degrees suffering constant diminution, their fragments are dislodged, masses are rolled into the valley, or carried by the rushing torrent into rivers, and thence transported to the sea. The lower and softer rocks are undergoing similar but more rapid destruction. The result of all this must be, the accumulation of much new matter in the ocean, which will be deposited in horizontal layers. Looking at the transition rocks of Werner, he perceives, that though not strictly crystalline, they appear made up of finely divided matter, more or less indurated, and sometimes very hard in texture, and of a vitreous fracture; and that this hardening is most perceptible when in contact with the primitive or inferior rock, which often pervades them in veins, or appears to have broken up or luxated the superincumbent masses. According then to Dr. Hutton, the transition or secondary rocks of Werner were deposited at the bottom of the ocean, in consequence of operations similar to those which are now active, and the primary rocks were formed beneath them by the operation of subterraneous fires ; their crystalline texture, their hardness, their shape and fracture, and the alterations they have produced upon their neighbours, are the proofs of the correctness of these views. It is by the action of subterraneous fire, then, that rocks have been elevated, that strata have been hardened, and that those changes have resulted which an examination of the earth's surface unfolds. The production of soils and of alluvial land, is considered as dependant upon causes the same as those referred to in the other theory.

It will be observed that Hutton refers to fire as well as water, for the production of our present rocks ; the former consolidating, hardening and elevating ; the latter collecting and depositing the strata. This system has been happily illustrated by many of the phenomena that occur among the mountains of Scotland, the birth-place of its inventor, and the seat of his speculations ; it has been elucidated by the eloquent and philosophic pen of Mr. Playfair, and has received other advantages and aids, which the Wernerian theory has not enjoyed. But these circumstances must not be suffered to bias an impartial story; it is to facts we must attend, and upon them found our verdict.

Much as has been said upon the mischief of geological theories which by some are represented as ingenious, though dangerous fictions, no one can justly deny their importance and utility, as furnishing strong incitements to the labour of observation and experiment. He that has framed a theory, is fond of searching for confirmations; and he proceeds with a zeal and enthusiasm widely distinct from the cold accuracy of the mere accumulator of insulated facts. In all physical inquiries, theory and observation should go together, like mind and body; the one guiding and directing the other. It is quite true, that the impartiality of an observer may often be affected by system; but upon this it has been justly remarked by Mr. Playfair, that it is a misfortune, against which, the want of theory is no security. The partialities in favour of opinions, are not more dangerous than the prejudices against them; for such is the spirit of system, and so naturally do all men's notions tend to reduce themselves into some regular form, that the very belief that there can be no theory, becomes a theory itself, and may have no inconsiderable sway over the mind of an observer. Besides, one man may have as much delight in pulling down, as another in building up, and may chuse to display his dexterity in the one occupation as well as in the other. The want of theory then, does not secure the candour of an observer, and may greatly diminish his skill. The discipline best calculated to promote both, is a thorough knowledge of the methods of inductive investigation, an acquaintance with the history of physical discovery, and the study of those sciences in which the rules of philosophizing have been most successfully applied.

LECTURE II.

Of the Succession of Strata encrusting the Globe, and of the Stratification of Britain in particular.—Granite, and its component Parts.—Its Aspect and Situation.—Comparison of the Huttonian and Wernerian Hypotheses concerning its Formation.

THE terms primitive and secondary rocks, which were employed in the description of Werner's Theory, given in my last Lecture, were introduced into geology by Lehman,* a correct and sensible writer of

* Traités de Physique, d'Histoire naturelle, de Mineralogie, et de Metallurgie. Par J. G. Lehman, et traduits de l'Allemand.—Paris 1759. " Les montagnes sont des élévations de la terre de différentes hauteurs, dont quelques-unes sont composées de parties dures, solides, et pierreuses; d'autres sont composées seulement de parties terreuses ; quelques-unes ont été créées en même tems que la terre, d'autres ont été formées par des accidens, ou par des évènemens qui ont eu lieu, en différens tems."—Vol. III. Sect. 3. " Il n'y a rien de plus naturel que de partager toutes les montagnes en trois classes. La première classe sera celle de montagnes qui

the middle of the last century. He considered the crust of the earth as presenting three distinct series of substances. The first, coeval with the world, he calls primative, or primary rocks. The second series are of more recent formation, and seem to have resulted from some great catastrophe, probably the deluge, tearing up, and modifying the former order of things; and the third class owe their for-

ont été formées avec le monde. La seconde sera celle des montagnes qui ont été formées par une révolution générale qui s'est fait sentir à tout le globe. La troisième classe, enfin, sera celle de montagnes qui doivent leur formation à des accidens particuliers, ou à des révolutions locales." "Les montagnes de la première classe sont élevées, dont quelques-unes se trouvent isolées dans des plaines; mais qui, le plus ordinairement, suivent une longue chaine et traversent des parties considérables de la terre. Elles diffèrent des montagnes de la seconde classe: 1. Par leur élévation et par leur grandeur, qui surpassent celles de toutes les autres. 2. Par leur structure intérieure. 3. Par les substances minérales qui s'y trouvent." Ibid.

These passages are sufficinet to shew the merits of Lehman as an original and acute observer, and have furnished subsequent geologists with the foundations of their arrangements.

mation to partial or local revolutions, as indicated by their structure and situation.

In collecting the materials of these Lectures, I have thought much of the best mode of arranging them, and conceive it most prudent to follow the succession just noticed: methods more philosophical might be adopted, but I have deemed it preferable to aim at perspicuity, and to consider that as most scientific, which experience has shewn to be most useful. I once wished to have commenced our inquiries with the present state of the earth's surface; successively to have removed and examined its strata, till we arrived at the greatest depths that have been penetrated, and at the matter which is considered as the nucleus of our planet. But such a plan was found to involve serious impediments to the student's progress; and though I am quite aware how much the contrary is the case, it is my duty to consider the audience that surrounds me, as beginners in geological science.

The sketch of the theories of the earth, will have suggested some of the objects of this branch of science; and it is no unworthy occupation of the mind, to speculate upon the events of former times, and thence to trace, through a series of successive ages, the causes which have produced the present order of things. It is a study which opens to the traveller new sources of amusement and delight, and amidst the sublime imagery of a mountainous district, the feelings naturally exalted, are yet more raised and refined by the contemplation of its uses and subserviency to life.

If the practical utility of geology be questioned, nothing is more easily demonstrated; and it augurs well that its pursuit in this respect is daily extending. To refer to two or three instances only, to mining, farming, and building.

We learn that certain rocks are more prolific in mineral treasures than others; that some yield nothing useful; that veins of the metals pursue certain courses; that coal is accompanied by favourable and unfavourable indications. Geology confirms, extends, and applies experience of this sort, upon which the miner's success depends. It enables the farmer to ameliorate his land, by teaching whence to procure mineral manures, and where to look for those associations of strata which are called for in agricultural improvements. The inattention of architects to the plainest truths taught by geology, is a matter of serious regret, as far, at least, as concerns great works of art, intended to endure as monuments of the present age. Nearly all the public edifices of this metropolis are constructed of one of the most perishable kinds of stone the island affords; which is the more reprehensible, as being often brought from the contact of that which is durable, and but a little more difficult of removal from the quarry. The only exception I am aware of, is in the Strand-bridge, where the durability of the material is equivalent to the skill of the architect.

In taking a general view of the substances which encrust our globe, for of its nucleus we know nothing, we perceive certain distinctions of texture and disposition, which are at once curious and important. The rocks which I have elsewhere called primitive or primary, are generally found in huge masses or blocks, not regularly stratified, and affecting in their fractures and fissures a vertical arrangement. Sometimes they are of perfectly homogenous texture, commonly hard and durable, and sometimes composed of two or three ingredients blended together; they are generally crystalline in their texture, and usually constitute the loftiest mountains.

The transition series of rocks, or those deemed by the Wernerians next in point of antiquity to the primitive, are less lofty than the former; they in many instances present a slaty texture; they seem to have been deposited in strata or layers, and these are seldom either vertical or horizontal, but variously inclined to the horizon. The secondary rocks, or the more recent series, are nearly if not quite horizontal in their position. In their texture they are soft, and consequently easy of decay: and they appear rather as mechanical deposits, than as chemical compounds which have resulted from fusion, crystallization, or solution.

These different series are tolerably regularly arranged in regard to each other. The primary rocks form the bases upon which the others rest; the transition, are immediately recumbent upon these; and these are succeeded by the varieties of secondary rocks, and by their detritus constituting alluvial matter and soils.

In selecting illustrations from nature of the different geological phænomena that come before us, I shall in all cases prefer reference to our own country; and I do presume that it would, on the whole, be difficult to select a better spot for the study of our science than Great Britain. We have every variety of rock presented under its various aspects; and though in foreign climes nature may have more liberally dispersed the sublime, she has no where more instructively or delicately diversified the earth's surface than in the small space allotted to the British isles.

There are also few parts of Britain which I have not personally visited; I shall therefore be able to select proofs and illustrations from actual observation.

A section of the south of England, from the coast of Cornwall, for instance, in the west, to London in the east, will furnish a good exhibition of the phenomena of stratification to which I have just alluded. It will begin at the Land's end with primitive rocks; massive and amorphous. Upon this rest several species of transition rocks, especially slates of different kinds, having various inclinations; and these are succeeded by secondary strata, deviating more and more from the vertical, and acquiring the horizontal position; and ultimately we attain the alluvial matter upon which the metropolis stands. It is principally clay, and has once perhaps formed the mud at the bottom of a salt water lake.

Proceeding from London northwards, towards the Scotch border, the order of stratification is reversed, and traversing a highly interesting series of secondary rocks, we arrive in Cumberland at some of the primitive series. The whole arrangement is such as to include the highest and oldest rocks upon the west side of England, forming a chain extending from the Land's end in Cornwall, to Cumberland, and thence to the northern extremity of Scotland. So that the length of Great Britain, and its general shape, appear in a considerable degree dependent upon this chain of mountainous land, and upon two lower ridges, which extend, in one direction from Devonshire, through Dorsetshire, Hampshire, and Sussex, into Kent; and in another, nearly from the same point, to the east of Yorkshire.

The western ridge is broken in upon in several places by plains and rivers, giving rise to so many chasms in the great chain.

In the Descriptive Catalogue of our Geological collection, an attempt has been made to follow the natural succession of strata in Britain, and to shew their successive alternations; and I trust that it will prove serviceable in connecting the observations which I shall have to make in these Lectures with their respective illustrative districts of our island.

Where the edges of the inclined strata are uncovered and visible upon the surface, they are said to *rise to the day*, to *basset*, or *crop out ;* and where horizontal strata happen to rest upon the edges of the inclined, they are said to be *in an unconformable overlying position.* But we should endeavour to shut these provincial vulgarisms, and foreign barbarities out of the language employed in scientific disquisitions, unless necessity pleads for their admission. For the same reason I would object to the anglicising Werner's phraseology, which only encumbers science "with an army of harsh and unwieldy words, poured in rather to conquer than assist the natives ;" nor would I adopt the terms orictognosie and geognosie, "merely because a foreign school has chosen to annex ridicule to the terms systematic mineralogy and geology."

Of the primitive rocks,* one of the most abundant in nature, and the most useful in its applications, is GRANITE, so called from its appearing to be made up of a

* In selecting specimens of rocks and strata for the geological cabinet, we should endeavour to shew their recent fracture, as well as their weather-worn surface, which is generally easily attainable.

number of distinct grains or particles. Its essential component parts are *quartz*, *felspar*, and *mica*.

Quartz is the substance commonly called *rock crystal;* it consists of pure siliceous earth, and is abundantly found in more or less regular six-sided prisms, terminated by six-sided pyramids. It occurs of various colours, such as rose, brown, yellow, and purple, metallic bodies generally giving these tints; and sometimes these varieties are transparent, and when properly cut constitute beautiful articles of ornamental jewellery. It is so hard as not to be scratched by a knife, and it cuts or scratches glass.

Siliceous earth is an important substance in some of the arts, and is an essential ingredient in glass, earthenware, and porcelain.

Chalcedonies, agates, flints, jaspers, and many other less known productions of the mineral world, consist principally of siliceous earth; but the term *quartz* is especially applied to the purer varieties.*

* Quartz is sometimes met with in mountain masses, which usually present a conical appearance. The quartz

Felspar, the next constituent of granite, is a compound body, of which siliceous and argillaceous earths are predominant ingredients: it generally contains a little lime and potash, and is often coloured by minute portions of oxide of iron.* Sometimes it is found crystallised, when it assumes the form of four and six-sided prisms bevelled on the extremities; its usual colours are red, white, and gray. It is softer than quartz, but harder than glass, and is cha-

is milk white, and of a more or less granular texture. The sugar loaf mountains near Dublin; the pass of Jura, in the Western isles of Scotland; and some of the mountains of Sutherland and Caithness, present instances of this formation.

* In a fine specimen of pale flesh red felspar, from the Alps, crystallized in the form of the oblique four-sided prism, I found the following constituent parts:

Silex - -	68,00
Alumine - -	20,00
Potash - -	8,30
Lime - -	2,00
Oxide of iron -	0,50
	99,00
Loss	1
	100,00

racteristically marked by fusibility before the blow pipe.

Felspar is a very important ingredient in many kinds of pottery; and the substance used by the Chinese, under the name of *petuntz*, is probably of a similar nature. The decomposing felspar of Cornwall is abundantly employed in the English porcelain manufactories, and as it contains no iron, it retains its perfect whiteness. According to Mr. Wedgwood it consists of,

60 Alumine,
20 Silex,
20 Moisture and loss.

There are some beautiful varieties of felspar employed in ornamental jewellery, such as the green and blue of Siberia and America; the foliated, pearly, or resplendent felspar, called adularia and moonstone; and the felspar of the island of St. Paul, upon the coast of Labrador, distinguished by the property of reflecting very beautiful colours when the light falls upon it in certain directions. Felspar is an important component of several other rocks, besides granite.

Mica, the third and last of the essential ingredients of granite, is a well marked compound mineral, consisting principally of argillaceous and siliceous earths, with a little magnesia and oxide of iron. Its texture is lamellar, and it is easily split into thin, flexible, elastic, and transparent plates. It is so soft as readily to yield to the nail: it is sometimes met with crystallized in four and six-sided plates and prisms. Its usual colours are shades of brown, and gray; sometimes it is red, and sometimes black. In some parts of Siberia mica is copiously quarried, and is employed as a substitute for glass in windows and lanterns. It has been thus used in Russian ships of war, where it has the advantage of not being shattered, like glass, by the discharge of artillery. The extreme tenuity of the plates into which it may be divided, and their elasticity, renders it very useful for the enclosure of objects to be submitted to microscopic inspection.

Such are the characters of the components of granite; in some specimens of which they may be distinctly traced and separated from each other, but sometimes the particles are so small, as to produce a compound, which to the unaided eye will seem almost homogenous. We have therefore *fine* and *coarse grained granite*. The former is abundant in Scotland, the latter in Devonshire and Cornwall: indeed the Cornish granite is remarkable for the well defined and large crystals of felspar which it contains, and which may be seen in many parts of London, where this rock has been used for paving, and where the crytals of white felspar have become evident in the mass, from the constant attrition to which it has been subjected. The foot way of Westminster bridge particularly occurs to me, as in this respect remarkable. It is of this stone that the Strand bridge is mainly constructed. The colour of granite is principally dependent upon that of the felspar it contains, though a dark mica will often give it a gloomy hue. It is commonly gray or reddish.

There are two rocks very closely allied to granite, and usually associated with it; I mean slaty granite, or Gneiss, composed of precisely the same materials as granite, but slaty in its fracture, owing to the comparatively large quantity of mica it contains; and the other rock is a compound of mica and quartz: it has a slaty texture, and also derives its leading characters from the large quantity of mica which it contains. It is called mica slate.

On the origin of granite, geologists widely differ. As it constitutes the basis upon which all other rocks appear to lie, Werner has regarded it as the first formation of that chaotic rock-depositing fluid in which he imagines the earth, once to have been enveloped. But many peculiarities of granite have been adduced by Dr. Hutton as contrary to such an opinion. If we examine a granitic district in nature, we shall observe in regard to it, two leading phenomena. The one is, that veins of granite frequently shoot from the great mass, into the superincumbent strata. The other, that the bodies lying upon granite, especially if they be stratified, either bear evidence of having been broken up, dislocated, and penetrated by the granite whilst in a fluid state; or they seem as if gradually elevated by some power which has thrown the granite up from below. So that upon this view of the subject, the date of granite, as far as concerns its present position, is posterior to that of the strata that rest upon it. They were first deposited; and the granite then erupted from beneath, and elevated the other strata, throwing them out of the horizontal, and giving them various inclinations to the horizon, or sometimes a vertical position. The Brochen mountain in Germany, St. Michael's Mount in Cornwall, and the granitic district at Aviemore in the Scotch highlands, will furnish illustrations of this subject. The first I select, as being at the same time one of the favourite proofs with the Wernerians of their master's theory, while the Huttonians may regard it no less favourable to the truth of their views.

Of this mountain the peak is granite, and upon it are regular layers of other rocks, the dip or inclination of which is regulated by the surface of the central granite. In inspecting a section of the Hartz mountain, it will I think hardly be denied, that the appearance is rather in favour of the elevation of the strata, by the eruption of the granite, than of the original deposition of the granitic nucleus, and the successive subsidence of the other strata upon it.

At St. Michael's Mount in Cornwall, a schistose or slaty rock is invaded by a mass of granite from beneath; veins of the latter penetrate the former, which is hardened, and broken, apparently by the force with which the granite has been protruded. Indeed the whole granite district of the West of England, beginning at Dartmoor in Devonshire and extending to the Land's end in Cornwall, presents appearances, which are no way so well accounted for as upon that hypothesis which considers the granite to have been thrown up from below, in a fused state, and to have forced its way through the superincumbent strata. There are four granitic summits in the promontory of Cornwall, all probably connected with each other, and with that at Dartmoor; and the surrounding country is principally clay slate, which every where inclines to the granite, in the same manner as the strata of the Brochen in the Hartz forest.

In the hill at Aviemore, to which I have alluded, veins of granite are seen penetrating the slaty rock in all directions; and upon the weather worn side, facing the north-east, a large vein of granite may be perceived, widest at bottom, running nearly perpendicular, and enlarging into a mass or stratum of granite between the schistose layers.

Such, then, is the appearance of granite, and such the arguments of the Huttonian geologist concerning its origin. I have mentioned that the superincumbent rocks are frequently penetrated by granite veins, and it is obvious that every vein must be of a date posterior to that of the body which contains it; and further, as the veins are often observed to proceed from the main body of the granite into the superincumbent strata, it may be argued, *that the mass of granite and the veins proceeding from it, are coeval, and both of later formation than the strata.*

Veins of granite, however, are frequently discovered which cannot be traced to any original mass or mountain; they seem to be insulated, as it were, among other strata. This is the case at Portsoy, and in Glentilt; and in some of the Western isles of Scotland, especially Tiree and Coll; and is also observed in many parts of Cornwall. Dr. Hutton, from collateral evidence, conceives that these are always united to some granitic mass, though too deep or at too great distance to be traced and discovered.

It may now be asked, how the pupil of Werner accounts for phenomena of this kind? I have already said, that he regards granite as having been deposited before all other strata, though its irregularity and its want of stratification are decided objections to such an idea, and that the other substances were precipitated upon it, in the order we find them. In these strata, cracks and fissures occurred, and a new deposition of granite took place from the chaotic fluid, confined to the said cracks and fissures, and producing the appearance of granitic veins, and the hardening of the neighbouring rocks, referred by the Huttonians to the heat of the injected granite, is accounted for by the infiltration of the aqueous solution, which has, as it were, lapidified the softer materials. Now, though we may imagine granite to have been in igneous fusion, we cannot easily conceive it susceptible of aqueous solution; and if so dissolved, why should its second deposition have been confined to the cracks and fissures; why should it not have formed a new stratum? With these facts in your possession, I shall not weary your attention with further comments; leaving you to embrace that hypothesis (for after all it is but hypothesis), which appears best supported by evidence derived from actual observation.*

* Some have regarded granite as a congeries of crystals of mica, felspar, and quartz, accidentally blended and united; the inspection, however, of the rock, clearly proves that all its materials have been together in fusion; for we find in some granites the quartz impressed by the crystals of felspar, and in others the felspar receives impression from the quartz. Dr. Hutton has looked upon this as demonstrating the igneous fusion of granite, for, (says Mr. Playfair) "had the materials been dissolved in water, one kind of crystal ought not to impress another, but each enjoy its own peculiar shape." This, however, I do not hold to be sound argument.

The aspect of a granite district in nature, is subject to variation; it, however, exhibits traits sufficiently peculiar, which are readily recognized by the traveller in his approach to it.

In Cornwall, and in some parts of Ireland, especially in the county of Donegal, the granitic rocks are marked by the bold and abrupt precipices which they present to the attacks of the ocean; and by the barren and dreary aspect of the inland plains, that seem like immense fields, in which blocks of the stone have been torn from their beds, and indiscriminately scattered over the moss-grown surface. The elevation of these districts is not considerable, the granite is coarse grained, and splits into immense blocks, separated from each other by natural seams, and appearing like the ruins of edifices constructed by a giant race.

In other cases, granite forms irregular and broken peaks, of prodigious elevation, and does not split into the blocks and masses just alluded to. This is the case in the Alps, and Pyrenees; in the highest

Scotch mountains; in the Hartz; and in the Tirol. In Asia and Africa granite constitutes the Uralian, Altaian, and Himalayan chains, and the Atlas mountains; and in South America, the lofty ranges of Cordilleras are of a similar description.

Some kinds of granite are prone to decomposition, being dissolved into a fine clay containing siliceous particles: this probably arises from a peculiarity of the felspar, afterwards to be noticed. In general, granite is the most durable of nature's productions, and long resists the destroying hand of time; as a building material, therefore, granite is unrivalled; and though in common cases its extreme hardness is against its employment, its use should be enjoined for public edifices. Dublin furnishes some noble examples of buildings constructed of granite, which is there procured in the immediate vicinity of the city, and of a very beautiful kind. In Wales there is very little granite; in the North of Scotland it is abundant; and in England it occurs in Cornwall, Devon, Westmoreland and Cumberland. It is also met with in smaller quantities in Worcestershire at the Malvern Hills, and in Leicestershire in Charnwood forest.

Although granite probably exists in great abundance below the earth's surface, the quantity visible above ground is comparatively small, perhaps not amounting to a hundredth part of the other primitive and transition rocks. In some parts of Scotland the granite superficies, however, is very considerable, and much exceeds the limits assigned to it by Dr. Hutton. Upon this subject a very acrimonious controversy arose between Dr. Hutton and Mr. Kirwan: the general statements however of the former, in this and other cases, commonly make much nearer approach to truth than those of the latter; but as human reason is not infallible, he who always contradicts must sometimes be right; and thus the mere cavilling disputant may occasionally discover the errors of the slow and cautious observer of nature.

LECTURE III.

Porphyry—Syenite—Serpentine—Marble.—Observations on the Composition of these Rocks, and on their Associations and Aspects in Nature.—Remarks on the general Characters and Arrangements of Primary Rocks.—Primitive Breccia in the Vicinity of the Fall of Fyers.

To the class of massive unstratified rocks belongs PORPHYRY, a substance which is ranked by Werner among the primitive formations. Its essential constituent is felspar; and genuine porphyry may be defined as massive felspar, containing embedded crystals of the same substance. Any rock including distinct crystals of felspar, is called *porphyritic*, as *porphyritic granite*, &c. The colour of porphyry, which is usually reddish, brown, and green, is principally derived from the base, or paste including the crystals. The common aspect of porphyry is that of blocks and masses, not very unlike some of the varieties of granite noticed in the last Lecture, but its fragments are generally smaller, and are in a more decaying condition. Porphyry is an extremely durable material for architectural purposes, and as such was highly esteemed among the nations of antiquity. It is met with in many parts of Britain ; and in the north, the porphyry districts are of singular grandeur, as at the base of Ben Cruachan, on the banks of the Awe, and amidst the frightful precipices of Ben Nevis, the highest of the British mountains.

The British porphyries are many of them of great beauty, and might well be substituted for all ornamental purposes, for the more rare and expensive foreign varieties.

Granitic rocks frequently contain a large proportion of *hornblende*, a mineral of a greenish black colour, which sometimes forms prismatic crystals; it consists of silicious and argillaceous earths, with magnesia, and appears to derive its colour from oxide of iron, of which it contains from 20 to 30 per cent. Hornblende sometimes passes into mica; and if the component parts of the two bodies be compared by analysis, the principal difference will often be found to consist in the hornblende containing excess of iron.

These aggregates are termed SYENITES, or *Syenitic* rocks, and are of various hues, according as one or other of the constituents predominates. Sometimes the place of the quartz is wholly occupied by hornblende, and the rock is principally an aggregate of felspar and hornblende. The term syenite is derived from Syene, in Upper Egypt, where this rock is plentiful, and was used for architectural purposes by the Egyptian and Roman sculptors. The aspect of syenitic rocks is allied to that of granite and porphyry. They may be observed rising from the slaty district of St. David's, in Pembrokeshire; and in Cumberland, near Wastdale and Buttermere. A beautiful syenite is noticed by Mr. Bakewell as occurring in Leicestershire, at Markfield Knowle, an hill on

Charnwood forest. Syenite very often contains magnetic oxide of iron.

Another substance belonging to the class of rocks we are now describing, is SERPENTINE ; its appearance is singularly picturesque and beautiful ; and it forms a delightful contrast to the sublimity of granitic districts. Serpentine has its name from the variety of tints which it exhibits, such as bright red, green, brown, yellow, and their various shades, and it often is prettily traversed by veins of a soft substance, to which the term *steatite* or *soapstone* has been given.

Fossils which are unctuous or soapy to the touch, which possess no considerable hardness, transparency, or lustre, and which have a greenish tinge, generally contain magnesia. Serpentine is a rock of this kind ; its principal constituents are silicious earth, magnesia, oxide of iron, and a little carbonate of lime.*

* Serpentine has been repeatedly analysed ; but the results are very discordant ; no doubt owing to the indeterminate nature of the rock. See Jameson's Mineralogy. 2 Edit. vol. i. p. 509.

Some of the varieties of serpentine admit of a tolerable polish, and such are very desirable for many ornamental purposes.

Serpentine is seen in Cornwall in characteristic beauty, forming part of the Lizard promontory on the southern coast of the county. It appears in variously shaped and coloured blocks and masses; it forms natural arches, columns and caves; and the district is of very singular interest from many concomitant circumstances, especially from the blocks of porphyry upon which the serpentine is incumbent, and the veins of granite associating with those of steatite, which pervade it.

Serpentine is met with also in the isle of Anglesea, upon the northern coast, near the celebrated Parys Mine,* and at Portsoy on the Murray firth in Banffshire, where it is associated with granite. The composition of serpentine, as relates to its proximate components, has been variously described. It is generally so fine grained

* Some of the serpentine of this district is of more brilliant colours, more hard and transparent than the ordinary serpentine; it belongs to the species called by

as to appear of an uniform texture ; but in Cornwall a coarsely aggregated rock, consisting of *felspar*, *talc*, and *schiller spar*, may be traced passing into the fine grained serpentine. I have already alluded to the nature of felspar.

mineralogists *noble serpentine,* of which the following analysis has been given by Dr. John.

Silica - -	42,50
Magnesia - -	38,63
Lime - -	0,25
Alumina - -	1,20
Oxide of iron - -	1,50
Oxide of manganese -	0,62
Oxide of chrome -	0,25
Water - -	15,20
	99,95

The following is the analysis of *common serpentine,* by the same chemist.

Silica - -	31,50
Magnesia - -	47,25
Alumina - -	3,00
Lime - -	0,50
Iron - -	5,50
Oxide of manganese -	1,50
Water - -	10,50
	99,75

Vide Chemische Untersuchunge. Th. 11. s. 208, 94.

Talc is a body somewhat resembling mica in appearance, but the plates into which it is divisible are not elastic. Its usual colours are various shades of green. It consists of nearly equal parts of silex and magnesia, with a little lime; not more than six per cent. It is met with in small tabular crystals.

Schiller stone, or *schiller spar*, is a term from the Germans, implying glistening or changeable spar: it is one of the varieties of *diallage* of the French authors; it is a silico-ferruginous fossil, containing

44 Silex,
24 Iron,
18 Alumina,
12 Magnesia;

its colour is dark green; its usual lustre is semi-metallic, varying according to its position, in regard to incident light.

Steatite is a subtance of different tints of grey and green, and from its very singular unctuous feel, has been called soapstone. It is somewhat abundant in the serpentine of Cornwall, one of the masses of which is called the soapy rock; it is here carefully collected for the porcelain works of Swansea, in which it forms a very important ingredient. It also occurs in the serpentine of Banff. Varieties of this substance are the nephritic stone, or jade, and the axe-stone, employed by the natives of the south-sea islands for making cutting instruments. According to Klaproth, Cornish steatite consists of

Silica	- -	45,00
Magnesia	- -	24,75
Alumina	- -	9,25
Iron	- -	1,00
Potash	- -	0,75
Water and loss	-	18,00
		98,75*

MARBLE is the last of the rocks belonging to the class I am now describing. It is also very abundant in the secondary rocks, but its characters are there different. Among primary rocks, marble is associated with mica slate, and serpentine; and it differs from marble belonging to other rocks, in its granularly foliated

* Vide Klaproth's Beiträge, V. Band, S. 24.

texture, and in the absence of organic remains. The most esteemed varieties are perfectly white, and free from veins; somewhat translucent, and susceptible of a good polish. These marbles are imported for ornamental purposes, especially for those of the sculptor. Nearly all the sublime works of the Grecian artists were sculptured in the marble from the isle of Paros in the Archipelago. Next in point of estimation is that of Carrara in Italy.* Of the coloured varieties, that of the Isle of Tiree is extremely beautiful; it is of a pale red, spotted with green hornblende. Marble is found in several parts of Scotland, and in some places of characteristic beauty, and

* White marble is abundantly quarried in different parts of the Alps. Near the summit of Mount Cenis, it is found fine grained and micaceous. There are several quarries in the Vallais, and upon the Italian side of the Simplon, and in the hills surrounding the Alpine extremity of Lago Maggiore. Hence, is obtained the beautiful marble of which the Cathedral of Milan is built, and likewise that intended for the completion of the magnificent triumphal arch, commenced by Napoleon at the northern entrance of that Capital. In some places it contains interspersed hornblende.

alternating within small limits, with other rocks. In Inverary park it may be seen in contact with mica slate and porphyry. Serpentine and marble are sometimes blended together, and they then form a valuable compound for ornamental purposes, which has been called Verd Antique. In the splendid serpentine of Anglesea, patches of marble are found, which much enhance its beauty. A very remarkable marble quarry is that of Icolmkil, or Iona, "that illustrious island, whence savage clans and roving barbarians derived the benefit of knowledge, and the blessings of religion." Syenitic rocks constitute the leading feature of this mansion of the dead, but at the south west point of the island is a bed of marble about 40 feet wide, bounded by vertical walls of hornblende rocks.* Near it is

* The marble is of the species called *dolomite,* distinguished from the true primary marble or granular limestone, by the tardy effervescence excited by pouring muriatic acid upon it, and by its containing magnesia; it is also finer grained, and its fracture more splintery

a mass of hornstone, and above the whole protrudes an immense vein of granite, surrounded by the marble, but from which it has been loosened, so as just to admit a person to pass between the two walls. That they have once been in contact, is proved by the granitic protuberances having correspondent indentations in the marble, and *vice versa.*

We have now considered a highly important series of rocks, and have enumerated their characters as insulated individuals. As a class, they present analogies which distinguish them from their superincumbent neighbours, and give them the stamp of a peculiar and distinct formation,

than that of common marble. The dolomite of Iona yielded to Mr. Tennant,

Carbonic acid	-	48,00
Lime	- -	31,12
Magnesia	-	17,06
Insoluble matter	-	4,00

Phil. Trans. 1799.

The dolomite of the Appenines yielded to Klaproth,

Carbonate of lime	65
Carbonate of magnesia	35

Beiträge. B. 4. S. 215.

either formed before organic beings, or under circumstances which have destroyed such remains.

In these rocks we seldom observe any regular stratification; they are constituted of amorphous irregular and various masses, and present no appearances of having been deposited from water. They are crystalline aggregates; and they are deeper in their situation than other rocks, which always appear incumbent upon them, and often elevated or heaved, as it were, by their operation.

They often break through the beds or layers that cover them, and rise to a very great elevation, forming the summits and peaks of the loftiest mountains. In England they are comparatively rare; in Cornwall there is abundance of granite, but it rises to no great height. Granite and its associates are found in Cumberland, but they are sparingly scattered over the county; and the romantic and picturesque aspect of the hills is chiefly derived from other species of rocks. In Wales the primary rocks are uncommon, and I know of no granite, but there is a portion to be found in the centre of Anglesea, near Gwindy, where its associations will hereafter merit notice.

In Scotland the districts composed of primitive rocks, and presenting their various aspects, junctions, and transitions, are full of grandeur and interest. Travelling northwards from Edinburgh, we enter upon mica slate at one of the highland passes, and crossing the Grampians, find their principal summits of the same materials. From Loch Tay to Killin, the same rocks continue, with beds of limestone. Ben More is a mica slate rock, of exceeding grandeur; it rises to about four thousand feet above the sea's level, and is thickly intersected with quartz veins. Ben Lawers, to the north of Loch Tay, is of similar composition; it is chiefly gneiss, associated with mica slate and quartz; and the same substances are found at Crag Caillach, and Schehallion, and contribute to the magnificence of the celebrated pass of Killikrankie, between Dunkeld and Blair in Athol.

I have thus represented the highest mountains in Britain as composed of granite and its associates; but these are mere trifling protuberances upon the earth's face, when compared with the exceeding heights of the Alpine chain, or the yet more elevated mountains of South America, which consist of the same materials. Ben Nevis, the loftiest of the British mountains, is situated in the south of Inverness-shire, and is four thousand three hundred and seventy feet high. Cairngorm, in the same county, is four thousand and fifty feet high. Mont Blanc in Switzerland has its peak elevated fifteen thousand six hundred feet above the level of the sea; it is the highest mountain of Europe; and Chimboraso, the highest summit of the Andes, is twenty thousand two hundred and eighty feet above the sea's level.

The reason why these excessive elevations present nothing but primitive rocks, and especially granite, (excepting, indeed, where they are volcanic,) may not at first appear quite obvious, for in the low lands the primitive are generally covered by secondary strata, which were also once probably incumbent upon their loftiest summits. It is likely that the destructive agencies of the elements have been so powerfully exerted in these elevated and unprotected regions, that the secondary rocks have yielded to their unceasing attacks, and have been carried towards the vallies by the rills and torrents, while granite and its durable accompaniments have more obstinately opposed the inroads of such resistless assailants.

At the same time, however, it will seem probable, that the granitic mountains have themselves suffered tremendous degradation, and that at a former period their summits were greatly beyond their present elevation. All this will appear more clear when the general characters of mountain chains, and the phenomena of their decay, are more directly under discussion. But several circumstances present themselves to the most superficial observer, which, in a language that it is impossible to misinterpret, announce the influence of destructive agents upon these apparently invulnerable materials. Prodigious masses of granite are often found among the secondary strata that form the valleys under primary mountain chains; they are insulated and unconnected with any general mass of the same material; and the more distant they are from the granite range, the more they are rounded and smoothened upon the surface. Of this description, are the boulders or blocks of granite, observed by Saussure upon the east side of the lake of Geneva. One of these, called *Pierre de Gouté*, is ten feet high, with an horizontal section of fifteen feet by twenty. In the valley of Chamouny, several similar blocks have fallen from the Aiguilles. Some of these have been transported between thirty and forty miles, and as several mountains and vallies are now interposed, their transportation must have taken place at a very remote date.

In the glen which separates the great from the little Saleve, there are many granite boulder stones strewed over a calcareous plane; and of these, several are supported upon a short pillar of limestone, resulting from the protection afforded to the calcareous rocks by the harder boulder, so that the height of the column becomes a measure of the wearing away of the surrounding country. This appearance has induced Saussure to assert that these stones are now in the very situation where they were left by the great aqueous torrent, or debacle, which tore them from their original bed, and brought them down from the high Alps; a conclusion, however, as Mr. Playfair has remarked, not altogether warranted by the fact. In some of the recesses of the Jura there are large and somewhat angular blocks of granite which have evidently been deposited in their present situations at very remote periods; the surrounding and impending heights being composed of limestone rocks, which form an amphitheatre round the present valleys. In the neighbourhood of Neufchatel, too, there is an enormous insulated mass of granite, which I am informed, has lately been visited by Mr. Playfair; it is as large as the celebrated foundation of the statue of Peter the Great, erected at Petersburgh, by Catherine II. which is composed of a boulder or detached block of granite, found in a bay of the gulf of Finland, whence it was transported to the Capital; its length was forty two feet, its breadth twenty seven feet, its height twenty one feet.*

In the isle Arran, an immense block of granite is found upon the shore, not only three miles from the nearest granite rock, but having also a bay of the sea intervening; and several similar instances might be adduced, proving the great ravages that have been committed even upon so hard, and unyielding a body as granite. We shall not then be surprised that the same agents acting upon softer materials, have made more successful depredations, and have in many instances completely denuded those granitic surfaces which were once clothed by secondary strata.

In Cornwall granite is sometimes of very rapid decomposition, and the streams which traverse these districts, deposit a

* See the "*Relation*" *par le Comte* Marin Carburi de Ceffalonie, &c. Paris, 1777.

finely divided earthy matter, resulting principally from the felspar, and much used in the potteries. Carglaise tin mine is situated in a decomposing granite of this kind, and presents a spectacle highly worthy the attention of the curious. The mine is a vast chasm in the granite rocks, and exposed to the day. The tin ore and schorl rock traverse it in abundant veins, and the surrounding peaks strongly remind the beholder of a miniature representation or model of the Alps. Possibly the rapid decay of the granite here, depends upon the quantity of alcali contained in its felspar.

Dr. Mac Culloch, in a dissertation on the granite Tors of Cornwall, published in the Geological Transactions, has made some interesting remarks upon the peculiarities which they present, and which have given rise to much idle and ignorant speculation. A very remarkable Tor, is the Cheese-wring, upon an eminence near Liskeard. It is a cairn consisting of five stones, of which the upper ones are larger than, and overhang the lower, the whole pile being fifteen feet high. The stones of which it consists are yielding to the weather, most rapidly at their angles and edges; they are thus becoming rounded, and approaching that tottering state which will soon hurry them down the precipice to their former companions in the plains below.

This tendency of square blocks of stone to become spherical, independent of friction, is productive, in other cases, of very curious consequences, and has often been considered as demonstrating the agency of streams or currents by which the masses have been transported from distant regions. The present Tor has by some antiquarians been considered as a druidical statue of Saturn. The same cause appears to have produced the celebrated logging stone.

Before we quit the subject of primary rocks, I wish to call your attention to a district of Britain which for grandeur of scenery and geological interest can I think scarcely be surpassed. I allude to the country between the eastern extremity of Loch Ness, and Fort George, and especially to the rocks over which the river

Fyers pursues its turbulent and winding course.

These are seen in characteristic grandeur in the neighbourhood of the small inn, called the General's Hut, and the scenery becomes more and more impressive and interesting until we arrive at the celebrated falls of the river. I should call the rock a *granitic breccia;* it appears made up of numerous angular fragments of granitic materials, held together by a siliceous cement, and the aggregate is of extreme hardness and durability: Masses resembling jasper and agate, may also be observed in it. Dr. Garnet compares the cement, or basis of the rock, to a *lava* of a reddish hue: and a common observer would consider the whole as fragments of granite which had been united by semifusion; which had been softened and glued together as it were in the fire. The general aspect of the surrounding scenery is such as to impress the mind with the idea of some vast convulsion of nature having torn the rocks asunder, and shattered them into gigantic fragments; rugged crags and abrupt precipices present themselves on all sides, and the river rushes with tremendous impetuosity through deep and obstructed chasms. A rude bridge is thrown over the upper fall, whence the spectator beholds the waters of the Fyers at the distance of two hundred feet beneath him, rushing into a cavity of seventy feet in depth, whence they again emerge in perfect stillness, and running over an uneven and fragmented channel, approach the lower or grand fall. Here " the country strikes the imagination with all the gloom and grandeur of Siberian solitude," and overlooking the stream from a small rocky prominence that overhangs it, we observe the channel torn through black piles and masses of stone, which obstruct the current till it comes to a descent of dreadful steepness and depth; here, the waters previously pent up and exasperated, suddenly discharge all their violence, and are lost in a horrid abyss. The depth of the chasm in which the river flows is four hundred feet, and it bursts forth in an unbroken stream, constituting a fall of two hundred and twelve feet perpendicular height. I was so fortunate as to arrive at this spot when the falls were in full dignity and terror, owing to previous rain, and every gleam of sun which penetrated the foliage of the surrounding firs and birch trees, was refracted by the spray into rainbows, that seemed dancing in the chasm. The rugged irregularities of this district, the fragments that lie thickly strewed upon the sides of its mountains, the caverns that abound in its rocks, and the perpendicular precipice of the great cascade, considered conjointly with the peculiar texture and composition of the materials that form it, present many objects worthy the attention of the geologist, and may be regarded as recording some great natural convulsion, which has not only broken up and reunited certain primary rocks, but has again disturbed their tranquillity and thrown them into the stupendous confusion they now exhibit.

LECTURE IV.

Stratified Rocks.—Transition and secondary Formations of Werner—Their Peculiarities—Clay-Slate or argillaceous Schistus —Grauwacke — Mountain Limestone—Red Sandstone—Their Aspects and Associations.

We now descend from the primitive to the *transition rocks* of Werner; I am speaking *generally*, for it is impossible to follow the Wernerians either with profit or amusement, into the nice, but hypothetical distinctions which they profess to make between the same kinds of rock, in different situations. These are more particularly the *stratified rocks* of the Huttonian geologists, and they are distinguished by several well marked characters from the unstratified and primary rocks.

One leading and general circumstance may be observed in regard to them, which is, that they never attain the great elevation of the primary bodies ; this has been elsewhere referred to the comparative readiness with which they yield to the assaults of decomposition and disintegration.

The highest known mountains in the world, are those of Thibet, constituting the Himalayan chain. They are alluded to by Col. Kirkpatrick in his History of Nepaul, and an extended and interesting account of them has been published by Mr. Colebrooke in the Asiatic Researches, Vol. XII.

Of this chain, the highest peak, covered with eternal snow, is called Dwawala-giri, or White mountain ; it is the Mont Blanc of the Indian Alps, and rises to the astonishing altitude of twenty-six thousand four hundred and sixty-two feet above the level of the plains of Gorakh'púr ; or upon the lowest computation, twenty-six thousand eight hundred and sixty-two feet above the level of the ocean. This is about six thousand feet higher than Chimboraso, eleven thousand feet higher than Mont Blanc, and twenty-two thousand feet higher than the most elevated peak of the British dominions, which indeed makes Ben Nevis seem very insignificant, though its summit is close upon the verge of perpetual snow in this climate. There can be no doubt that the lofty peaks of the Thibet chain are granite, though we learn that the hills which border them are secondary, and contain remains of spiral shells, in which the untutored mind of the Hindu discerns traces of Vishnu, his deity. The elevation of secondary rocks will in great measure depend upon that of the primary materials beneath them; thus in the Andes they attain twelve thousand feet; in the Alps seven thousand; and in this country not more than three thousand five hundred.

In respect to the original formation of secondary rocks, the notions of the Wernerians and Huttonians are not so widely different as we have found them formerly; they both agree that they are depositions from water; but how then have they lost their necessary horizontality and acquired positions more or less inclined, or even sometimes vertical? Dr. Hutton conceived they were elevated and hardened by the throwing up of the primary or unstratified rocks from below, in the state of igneous fusion. It was once a great difficulty to imagine a combustible which should thus furnish fuel to melt these immense masses of primary materials, and to conceive the real cause of that expansive power of heat which Dr. Hutton always flies to. But the discoveries of Sir H. Davy concerning the true nature of earthy bodies, have furnished unexpected evidence in defence of these apparent incongruities of the Huttonian doctrines, and it is bestowing no small praise upon a theory to allow that it is strengthened by the progress of knowledge and elucidated by the advances of experimental research. However, that these elevating powers do exist, is proved by the sudden throwing up of a hill in the Bay of Naples, which was raised one thousand feet in a single night, and by the appearance of a new island at the Azores in water between fifty and sixty fathoms deep. We must refer the *cause* of these phenomena to a future Lecture. At present, possession of the fact is the main requisite. In the Neptunian system it is conceived that the position of the strata has depended upon the ground they have been deposited upon, and that they have partly crystallised and partly subsided upon the inclined or nearly vertical sides of primary rocks, or that the falling in of caverns has occasioned their present irregularities; but when we observe the mischief which the primary rocks seem to have done the secondary, and when we take into the account all the phenomena of granite veins, before discussed; I think that he who is not unduly biassed, who has built his opinions not upon the papers of theorists, but upon the rocks of nature, will feel inclined to acquiesce in the Huttonian interpretation. It is probable then, that the materials of the transition rocks, or, as I would rather put it, of those secondary and stratified rocks which are immediately incumbent upon the unstratified primitive rocks, are derived from the destruction of a former order of things; that they have been delivered into the ocean by the rivers, that they have covered the bottom of the sea, and have been hardened, elevated, and traversed by the eruption of granitic and other substances belonging to that class, from the bowels of the earth.

The next peculiarity of the secondary rocks that presents itself, is their containing fragments, pebbles, and organic remains; whence cosmogonists have framed sundry conclusions concerning the particular period of their formation, which for reasons contained in my first Lecture, it will be unwise and useless to discuss. At the same time, the presence of bodies which once belonged to the organised kingdoms, but which, although still retaining their original forms, are completely fossilized, furnishes us with many interesting conclusions, and holds out to the inquisitive, unfailing matter of useful discussion. In the oldest secondary rocks, fragments are often found, and rounded pebbles, whence we learn their origin from former rocks. Upon these, beds occur, which contain remains of shells, corals, and fish, all of marine origin; and oftentimes the races are extinct. Approaching the newer rocks, relics of quadrupeds now no longer known, are observed; and following the deposition of strata, we ultimately arrive at remains of lizards, crocodiles, elephants, deer, and some other animals: and we occasionally discover districts containing land and sea shells in alternating layers.

I merely make allusion to these facts to shew how curious and new is the field of inquiry, which modern geology has opened. It has taught us that whole races of animals have been swept from the earth's surface; that not only species, but likewise genera, have become extinct; that fresh water and dry land existed before the formation of many of our secondary strata; that oviparous quadrupeds began to exist along with fish, nearly at the commencement of the secondary formations; that mammiferous sea animals are of more ancient formation than land animals; that a few of these now known, existed towards the termination of secondary formations, but that by far the greater number are of later date, and probably contemporary, with the present order of the earth's surface, for their bones are only discovered in very recent depositions, and are in a state of inferior preservation to those of more ancient date; and lastly, it is to be observed that no fossil human remains have yet been found.

Such are some of the topics which this part of geology presents for consideration, and which shew us, that the earth is indeed "as a book in which men may read strange matters." Though the existence of fossil remains must have been noticed from the earliest ages, the philosophical discussions to which they have given rise are of very modern date, and the merit of fixing the geologist's attention upon them, as recording certain revolutions of the globe, belongs exclusively to Cuvier.

Further, to promote attention to the nature and arrangement of the secondary rocks, it may be suggested that they are the chief repositories of metallic substances, and that by their decomposition and decay they furnish the principal materials of the soil in which the vegetable has its habitation, and consequently upon which the existence of animals ultimately depends.

Of the secondary rocks, CLAY SLATE

may be first noticed; it is extremely abundant, and generally immediately incumbent upon the primary series. It is often micaceous near the junction, and we frequently observe it fragmented, and penetrated by quartz, or felspar, or mica, or by granite itself. Before the blow-pipe, it fuses into a black mass; its usual colours are various shades of grey, and it is generally so soft as to yield to the nail. Siliceous and argillaceous earths and oxide of iron with a little lime and magnesia are its principal ingredients.* The varieties of slate are applied to various useful purposes; that which is easily separable into thin plates, compact, sonorous, and not injured by the application of a moderate heat, is employed for roofing houses. London is chiefly supplied from Bangor

* I obtained as the results of the analysis of a specimen from Luss near Dumbarton, the following component parts:

Silicious earth - -	48
Aluminous earth - -	28
Magnesia - -	5
Lime - -	2,5
Oxide of iron -	10
Loss - - -	6,5
	100,0

in Caernarvonshire, and from the neighbourhood of Kendal in Westmoreland. There are very large quarries at Easdale, in Argyleshire; according to Mr. Jameson five millions of slates are there annually manufactured, which gives employment to three hundred men. There are several slate quarries of note in Dumbartonshire; one ought particularly to be mentioned at Luss; it is of geological interest, and commands a captivating view of the lake, and the neigbouring mountains. Here the clay slate rests upon mica slate; the former is of a purplish tint, penetrated by veins of pink carbonate of lime, and of quartz; the latter is very remarkably contorted.

Other varieties of clay-slate are used for writing slates, slate pencils, &c.; and where slate is very abundant, we observe it employed for monumental tablets, pavements, and walls. Crystals of iron pyrites, and some other extraneous bodies are not rare in slate; these generally render it unfit for the applications I have alluded to. Slate often contains fragments of other rocks, embedded masses and nodules of various kinds, frequently pebbles, and occasionally, a few impressions of shells; it also often derives a green colour from the presence of a mineral called *chlorite*, consisting of oxide of iron, united to silicious and aluminous earths. The slates containing embedded matters are called *grauwacke-slates*, or when of a less slaty fracture, simply GRAUWACKE, a substance which is abundant in this country.

The slate district of England is of considerable extent, and neither wants sublimity nor grandeur; it follows the great primary chain which I before alluded to as running north and south upon the west side of England; in Cornwall the slate is seen immediately incumbent upon granite, and the slaty districts form very beautiful scenery upon many parts of the coast. The term *killas* has been applied to it by the miners. Nothing, I think, can exceed the scenery about Looe, Fowey, and the country between it and Falmouth; and upon the north coast, Tintagell is yet more remarkable.

There is some grauwacke in Cornwall, but it is not abundant. The best marked specimens I have seen, are from Mawnan near Falmouth, where it alternates with clay slate.

The slate district of Wales is of singular interest and magnificence, as those will acknowledge who have visited the chain of mountains, including Snowdon, Plymlimon, and Cader Idris. These mountains attain an elevation of between three and four thousand feet, their summits are jagged and irregular, their declivities steep and barren, and the neighbouring passes and valleys have all the peculiarities that slate confers; among them, the dell of Aberglaslyn, viewed from the bridge which unites Merionethshire, to the county of Caernarvon, presents a grand and awful feature. The rocks are lofty, lonesome, and black; their sides exhibit terrific and inaccessible precipices; or where he slopes are more gentle, they are covered with the sharp angular fragments, which time and the elements have dislodged from above.

Advancing northwards, the mountain chain is broken by the lowlands of Lancashire; but in Westmoreland and Cumberland slate again presents itself, plentifully accompanied by grauwacke, which contributes to the enchanting scenery of the lakes. As black peaks and precipices strewed with slippery and cutting fragments mark the mountains of common slate, so have the grauwacke rocks peculiarities by which they are recognized, and which are no where more evident than in the rounded summits that imbosom Derwent water. In their forms, tints, and outlines there is something indescribably delightful, and they present that rare union of the sublime and beautiful of which no better idea can be formed, than that suggested by Mr. Burke's comparison: "Sublime objects are vast in their dimensions; beautiful ones comparatively small; beauty should be smooth and polished; the great, rugged and negligent; beauty should shun the right line, yet deviate from it insensibly; the great, in many cases loves the right line, and when it deviates it often makes a strong deviation; beauty should not be obscure; the great ought to be dark and gloomy; beauty should be light and delicate; the great ought to be solid and even massive." These qualities of that which is sublime, well apply to the rocks I have before described, and when blended with the parallel definition of the beautiful, furnish a just notion of the aspect of those now under consideration.

The transition LIMESTONES of the Wernerians, are the substances that next occur. They are frequently seen immediately incumbent upon clay-slate, and are further distinguished from primitive limestone, or statuary marble, by having a less decidedly crystalline texture. Where this rock lies directly upon slate, it contains few organic remains; but where red sandstone is interposed between it and the slate-rocks, or in proportion as it is distant from the primary and slate rocks, the relics of organization become more frequent. It then abounds in remains of corals and zoophytes, which now are not known to exist.

It often is traversed by veins of calcareous spar, and presents a great variety of colours. It is abundant in Devonshire, South-Wales, Derbyshire, and Yorkshire; and is commonly known by the name of *Mountain Limestone*. At Plymouth, this rock is seen immediately incumbent upon slate, in a quarry between the Dock and the Town. Its colours are red and gray, streaked with white crystalline veins. It is also seen to great perfection in the Breakwater quarries at Oreston, whence 600,000 tons have already been removed, and it is supposed that as much more will be required, to complete this enormous barrier to the violence of the ocean.

I was upon the Breakwater in the summer of 1815, and found it about four feet above high-water mark in the centre. It had resisted the violent storms of the preceding winter, and during the severe gales, ships already rode safely in the Sound. It is about a mile in length, 100 yards wide at the base, and intended to be 10 wide, where above water. Many of the masses of marble used in this curious undertaking weigh more than 10 tons; they are merely thrown one upon the other, and weeds gradually cement them.

Slate and lime-stone districts often present very curious inflexions and incurvations of their strata. The slate at Plymouth, and the Grauwacke of Clovelly in the North of Devon, and the killas upon the coast of Cornwall near Charlestown, are in many places very singularly contorted; and sometimes small undulations present themselves in the laminæ, exactly resembling those left by the ebbing tide upon a gently inclining sand bank. These appearances may, perhaps, be referred to the action of water upon the materials before they were consolidated.

Limestone strata are also very remarkable for the inflections and curvatures, referred by Dr. Hutton to their having been in a soft state at the time they were disturbed from their horizontal position. There are some very curious instances of these curvatures noticed by Saussure; one in particular on the road from Geneva to Chamouny, where the small stream of

Nant D'Arpenay forms a cascade by falling over a perpendicular surface of limestone rock; the strata are bent into regular arches, with the concavity to the left; while in another neighbouring mountain they turn to the right; so that a vertical section of the two would present the figure of S. The top of Benlawers in Perthshire, and the coast of Berwickshire, with many other districts in Scotland, present instances of these singular contortions. Dr. Hutton has given a plate of the bent strata in Berwickshire, from a drawing made by Sir James Hall. In the period allotted to these Lectures, I cannot follow Dr. Hutton and his sagacious commentator through their arguments founded upon these phenomena, which are at once ingenious and satisfactory; they seem to prove that the undulated strata have received their peculiarities upon level ground; that they have then been elevated, hardened, and often bent and contorted during these processes; and that their irregularities, as to position, and their fractures and dislocations have thus occurred, and do not result, as the opposite school would have it, from the falling in of caverns,—a position which they assume as at once accounting for such appearances, and for the retreat of the ocean. Hutton considers the land to have been raised, Werner supposes the waters to have retreated.

Mr. Playfair very justly eulogizes this part of the Huttonian hypothesis, as more especially surpassing others. "The phenomena," he says, "to be connected are here extremely various, and even in appearance contradictory; the horizontality of one part of the strata, the inclined or vertical position of another, the perfect planes in which one set are extended, the breaking and dislocation found in a third, and almost every where the utmost rigidity and induration combined with appearances of the greatest softness and flexibility, the preservation of a parallelism of superficies in the midst of so much irregularity, and the assumption of a determinate species of curvature, under circumstances the most dissimilar; all these appearances were to be connected with one another, and with the consolidation of the strata, and this is done by the two-fold hypothesis of aqueous deposition, and the action of subterraneous heat. When these circumstances are fairly considered, and when the shifts which other systems are put to on this occasion are remembered, I think it will be granted that few attempts at generalization have been more successful than that here made by the Huttonian Theory."

The aspect of a country of mountain limestone is peculiar, and generally extremely picturesque. The hills, which, in this country at least, are not very lofty, abound in precipices, caverns, and chasms, and when upon the coast, form small promontories, and jut out in low but grotesque pillars. The even surfaces are covered with a stinted turf, but the rifts and cracks contain often a soft rich soil in which stately timber trees flourish. The chasms of limestone rocks are often filled with a fine clay, which has, perhaps, sometimes been derived from the decomposition of shaly strata, or sometimes deposited from other causes in the fissures, and the singularities of aspect, and much of the beauty of this rock, is referable to these peculiarities. Thus, upon the banks of the Wye, large and luxuriant trees grace the abrupt precipices, and jut forth from what appears a solid rock. Their roots are firmly attached in some crevice filled with a favourable soil. Sometimes rivers force their way through the chasms; at other times they are empty, and the roofs ornamented by Nature's hand with stalactitical concretions of white and glistening spar, which seem like the fretted sculpture of Gothic architecture.

The delicious views of Matlock, and its vicinity; and the caves of Castleton, are admirably illustrative of the scenery of mountain limestone. Pont-Neath Vaughn in Glamorganshire, is full of its beauties; and the Panorama of Swansea Bay, seen from the Mumbles point, furnishes a pleasing, characteristic, and perhaps unrivalled, prospect of these rocks.

The banks of the Avon too, in the vicinity of Chepstow, are of mountain limestone. The rock is there impregnated with bitumen, and hence exhales a peculiar and fetid odour when submitted to the blows of the axe or hammer. This is by no means uncommonly the case where the limestone rock, as in the present instance, is in the vicinity of coal.

Mountain limestone is an excellent material for building, and many of its varieties are sufficiently indurated to receive a good polish, and are thus employed for ornamental purposes, being cut into vases, chimney-pieces, and the like. Where they abound in corals, and other organic remains, these frequently add to their beauty.

The colours of transition limestone are various, but its essential constituent part is always carbonate of lime. The black variety known under the name of *Lucullite,** or black marble, has long been admired, and is often tastefully manufactured and

* A name given to this marble, in consequence of the admiration bestowed upon it by Lucius Lucullus. *Vide Plinii Hist. Nat.* 36. 8. " Post hunc Lepidum ferme quadriennio L. Lucullus consul fuit, qui nomen (ut apparet ex re), *Luculleo marmori* dedit, admodum delectatus illo, &c."

ornamented by etching upon its surface. It is found in Derbyshire, Sutherlandshire, and Galloway, and contains, according to Dr. John, the following ingredients:

Lime - - -	53.38
Carbonic acid - -	41.50
Carbon - - -	0.75
Magnesia, and oxide of Manganese	0.12
Oxide of iron - -	0.25
Silica - - -	1.13
Sulphur - - -	0.25
Potash, combinations of Muriatic and Sulphuric Acids, and Water	2.25

All these limestones are converted into a more or less pure *quick lime* by the operation of a red heat, and are thus often valuable as affording manures, and for other purposes.

The next rock that occurs in point of succession, is Red Sandstone. It often rests upon slate, and from its position has acquired the term of *old red sandstone* Although the metals begin to fail in this and the superior strata, yet it is connected with coal, and rock salt.

Entering upon this substance, we come upon distinctly stratified ground; it is very abundant in England, especially in Lancashire, Cheshire, Staffordshire, Shropshire, and Worcestershire; and independent of its embowelled treasures, its surface is generally favourable to vegetation, and its soil sufficiently luxuriant. It consists principally of siliceous particles, and oxide of iron, with some argillaceous earth, and more or less calcareous matter. Its beds are often of great thickness, as may be seen in the quarries; it is much used as a building stone, but moulders in consequence of the action of air and moisture upon the oxide of iron. It often contains particles of mica, and fragments and pebbles of old rocks.

Red sandstone rocks are seen in some parts of Britain in great beauty and perfection, especially where they occur on the coast, or are intersected by rivers. At Ilfracomb, the red sandstone of the Somersetshire coast is seen lying upon slate; and the junction is interesting to the geologist, the sandstone becoming somewhat slaty, and the slate having a tendency to a granular fracture. Hawthornden near Edinburgh shews the characteristic features of the rock; and the ancient castle, with its dungeons and vaults, is constructed of this material. Ridges of red sandstone, containing mica and fragments, sometimes accompany primary rocks, of which a very singular instance occurs upon the banks of Loch Beauly, near Inverness; a high range of granite is here bordered by a breccia, very like that of the bed of the Fyers; and a low ridge of red sandstone, of which the valley is also composed, accompanies the series, and seems the detritus of the more ancient and lofty formations.

LECTURE V.

Subjects of the last Lecture continued.—Gypsum—Rock Salt—Coal, &c.—Oolite—Chalk—Alluvial Formations—Fossil Remains—Basalt.

THE slates, grauwackes, and limestones, described in my last Lecture, are the principal seats of the metallic ores; and, as I had occasion to state, they form scenery which, gradually decreasing in grandeur and sublimity, increases in softness, variety, and luxuriance. In the lowest sandstone formation, the general position and aspect of which were also noticed, we meet with a variety of bodies of the utmost importance in our arts and manufactures; to these I shall beg briefly to direct your attention, before we advance to the superincumbent strata.

A substance which occurs in abundance in many parts of the red strata, is GYPSUM, or *sulphate of lime*, known also under the name of *plaister-stone*, *selenite* and *alabaster*. Near Tutbury in Staffordshire, and near Nottingham it is found in blocks and veins, and lately a variety new in England, has been found, called *Anhydrite*.* These minerals constitute valuable materials for the ornamental manufactures of Derbyshire.

In the county of Cheshire the red sandstone contains immense beds of COMMON SALT, most abundant in the valley of the Weaver; and near Middlewich, Northwich, and Nantwich, it is accompanied by gypsum. The first stratum was discovered

* Common gypsum or sulphate of lime, consists of

46.5	sulphuric acid.
32.5	lime.
21.	water
100.	

Anhydrite is composed of

55	sulphuric acid.
40	lime.
5	siliceous earth.
100	

When the former variety is heated to redness it loses water and falls into a powder, which when ground fine is commonly termed *Plaister of Paris.*

about 150 years ago, in searching for coal. It begins about 30 yards from the surface, and is 25 yards thick; below this, and separated from it by 10 or 12 yards of indurated clay, is another bed of salt, the extent of which is unknown; in many places of extreme purity, in others tinged with oxide of iron and clay. This pit is at Northwich; and at other places there are very abundant brine springs. A most remarkable circumstance in the Northwich mine is the arrangement of the salt, giving rise to an appearance something like a mosaic roof and pavement, where it has been horizontally cut. The salt is compact, but it is arranged in round masses, five or six feet in diameter, not truly spherical, but each compressed by those that surround it, so as to have the shape of an irregular polyhædron. The Wernerians regard the salt as having merely crystallised here from its aqueous solutions; the Huttonians consider the water to have been evaporated by heat. The large pit at Northwich presents a very singular spectacle when duly illuminated; it is a circle of nearly two miles in circumference; the roof is supported by massive pillars of salt, and the effect is heightened by the variety of colours it presents.

Coal is the most important product of these middle strata. What is called a *coal-field*, or *district*, or sometimes a *coal basin*, may be regarded as a concavity, varying greatly in extent, from a few to many miles, and containing numerous strata or seams of coal of very various thickness, alternating with sandstone and clays, and soft slate or *shale*, containing impressions of vegetables, and sometimes the remains of fresh water shell fish. The parallelism of these strata is generally well preserved. The whole arrangement is seldom any where quite horizontal, and never vertical, but almost always more or less inclined. Beneath each stratum of coal, there is often one of soft clay or *clunch*, which rarely contains the organic remains of the overlying shale; and although the alternating strata of coal be very numerous, it is seldom that more than three or four will afford profitable occupation to the miner. The upper seam is commonly broken and impure; and few beds, less than two or three feet in thickness, are followed down to any considerable depth. The depth of the mines will of course greatly vary, according to the inclination of the strata, the time they have been worked, and other circumstances. Our deepest mines are in the counties of Durham and Northumberland, and the thickest beds are found in Staffordshire. The most productive vary from six to nine feet.

There are several varieties of coal, but as far as their economical applications are concerned, they may principally be reduced to two. The coals of Lancashire, Scotland, and most of those raised upon the west of England, burn quickly and brilliantly into a light ash: while the coal of Northumberland and Durham, becomes soft and puffy, spouts out bright jets of flame, requires poking to continue in combustion, and produces bulky cinders, which if urged in a violent fire, or mixed with fresh coals, run into slags and clinkers. Though coal is chiefly found in the geological position I have mentioned, constituting the *independent coal formation* of Werner; it is likewise found in other situations, amongst newer rocks, and sparingly in alluvial soils. But in this country, the main coal formations are marked by their position, their contiguity to limestone, and often to slate, by micaceous grits and sandstones, and above all by shale with vegetable impressions, decomposing into tenacious blue clay.

The greater number of geologists are now unanimous as to the vegetable origin of coal; and indeed its composition, the abundance of vegetable bodies with which it is often associated, and the gradual transitions of wood into coal discoverable in many parts of the world, may be considered as satisfactory evidence upon this subject; but how it has been formed, is another and more intricate question.

Dr. Hutton considered coal strata to have been produced by the operation of subterranean heat in the manner already described, acting upon vegetable bodies and charcoal under exceeding pressure, which prevented the usual phenomena of combustion, and hindered the escape of the inflammable part. Sometimes, he observes, more or less bitumen has been driven off, for we find it in other strata.

By Mr. Williams, antediluvian timber and peat bog have been regarded as the source of our present coal; and a variety of curious circumstances, which the minute history of coal fields present, might be adduced as favourable to his conclusions. But I must wave the discussions of these controversialists, as it is my business to employ our time in the consideration of facts, rather than hypothesis.

The coal miner is often seriously interrupted in his proceedings by large fissures or breaks in the strata, and by veins of a hard black rock, which cut through the coal; sometimes merely dividing it, at others, throwing it out of its former position. It is in the neighbourhood of these *dykes* and *troubles*, as they are called by the miners, that immense quantities of carburetted hydrogen gas are frequently evolved, though the coals themselves, and the cavities in their strata, also yield it; it constitutes the *fire-damp* of the mines ; and when it has any where collected so as to constitute more than $\frac{1}{13}$ of the volume of atmosphere, it becomes explosive whenever a flame is presented to it, and the source of such dreadful destruction, that the mind recoils from the recital. Hitherto the miners, in these dangerous situations, availed themselves of the light obtained by the collision of flint and steel, which, however, was by no means free from danger; the repeated accidents, and their alarming increase lately, induced Sir H. Davy to turn his mind to the subject, and he has succeeded in discovering, not merely a perfect security from accident, but one which is easy of application, and very simple in construction.

His *Miners' Safety-lamp* consists of a common oil lamp, the flame of which is every where surrounded by wire-gauze, the apertures in which should never exceed $\frac{1}{20}$ of an inch square ; the wire of which it is constructed may be from $\frac{1}{40}$ to $\frac{1}{60}$ of an inch in diameter, and of iron or brass, but the former is preferable. Sir H. Davy has lately constructed some lamps of *twilled* iron gauze, containing 16 wires in the warp and 30 in the weft. This material is nearly as permeable to the light and air as the ordinary gauze, and is much stronger, so that it will resist blows and pressure. An account of these lamps will be found in the first volume of the Journal of Science and the Arts, p. 1. and in Vol. II. p. 464; and a more detailed history of the invention is printed in the Philosophical Transactions for 1816. The *principle* of *safety* consists in the cooling power of the wire in regard to flame. If a piece of wire-gauze, sufficiently fine, be held horizontally in the centre of an inflamed jet of carburetted hydrogen gas, it will cut off the upper half of the flame, while the lower half continues to burn; the gas passes through the wire, and the upper half may still be inflamed again in the usual way, after having been so far cooled by the intercepting wire as to be extinguished. So, in the wire cage of the lamp, the gas flame continues to burn, but it cannot make its escape through the wire in an inflamed state, so as to cause an explosion of the external atmosphere.

To the peculiar merits and singular importance of this discovery it is needless to advert; it ranks among the most valuable presents which philosophy has conferred upon the arts; it has already been advantageously employed in mines scarcely before accessible, and its use is daily extending.

Another substance which very often attends coal formations, is *argillaceous ironstone*, both in layers and nodules; and although a poor ore of iron, very seldom yielding more than 30 per cent. of metal, it becomes, from its association with coal and limestone (substances required for its reduction), a most important natural product; it is the main source of the enormous quantities of iron manufactured in this country; and the history of the various difficulties which have been surmounted in completing the processes of its reduction, presents an unrivalled picture of skill, ingenuity, and perseverance.

Leaving the districts of red sandstone and red marl, we observe a change in the general aspect of the country. There are no steep or abrupt precipices; the hills assume a more picturesque and luxuriant character, and the rugged features of primary country, are here softened down into gentle slopes and verdant plains.

The rocks which now occur are chiefly varieties of limestone and sandstone, particularly prolific in organic remains; among which we discern a number of species of which no living semblance is now in existence.

Corals, zoophites, ammonites, belemnites, nautili, and a variety of other fossil remains are found in the *argillaceous limestones*, which succeed in position to the red sandstone, and which are often called *white* and *blue lias limestone*. The coast of Dorsetshire, between Weymouth and Lyme, presents a very interesting section of these strata; and their continuation through the country is well entitled to the notice of the geologist. They decompose into marl, and furnish an ingredient in the best water cements. Sometimes they are of a peculiar yellow colour, and contain magnesia, when the fossil remains are less frequent.

These strata are succeeded by a species of stone often called *Bath-stone*, from its abundant occurrence in the vicinity of that city, and *free stone*, or *oolite*, of which Portland stone is a notorious variety. There then commonly occur various *sandstones*, with veins of chert and oxide of iron; and lastly we arrive at *chalk*, and superincumbent *alluvial* matters.

The examination of the fossil remains in these strata, leads to conclusions of much interest and importance. In the strata upon the coast of Dorsetshire, below the chalk, we find the remains of crocodiles or alligators; but there are no fossil relics of mammiferous land animals, either here, or in the chalk itself, whence it has been concluded, that oviparous quadrupeds are of more ancient date than those of the viviparous class, and that dry lands and fresh waters existed before the formation of our present chalk. In the vicinity of Paris, the chalk is covered by a coarse shell limestone, in which the bones of mammiferous sea animals have been found by Cuvier; but no bones of mammiferous land quadrupeds occur, till we reach the more recent and superincumbent strata. The chalk itself presents the geologist with much matter of speculation. In England it is a very abundant formation; and the round backed hills covered with verdure, which mark the eastern counties, are very characteristic of it. Salisbury Plain and Marlborough Downs form a centre whence the chalk emanates in a north-eastern direction, through the counties of Buckingham, Bedford, and Cambridge, and terminate on the Norfolk coast. In an easterly direction it traverses Hampshire, Surry, and Kent, and terminates at Dover; and another arm passing through Sussex east-south-east, forms the South Downs, and the lofty promontory of Beachy Head. Parallel ridges of sandstone generally accompany the chalk, and in Wiltshire, Berkshire, and some other counties, large blocks of granular siliceous sandstone, lie scattered upon its surface: of these the celebrated druidical relics called Stonehenge, appear to have been constructed, with the exception of one of the blocks, which is of greenstone. The lower beds of chalk are generally argillaceous, or marly, and contain no flints and few organic remains. The upper beds abound in fossil relics of the kinds before alluded to, and in flints sometimes regularly arranged in distinct nodules, at other times remarkably intersecting the chalk in thin seams. The formation of flint has been much speculated upon, but no plausible theory has yet been adduced in regard to it.

In the south of England the chalk is covered with gravel and clay, the history of which is extremely curious, on account of the fossils which they contain, and the evidence they afford of repeated inundations of salt and fresh water upon the same spot. There are two celebrated concavities filled with such materials, which have been called the London and the Isle of Wight basins. The former is bounded by the chalk hills proceeding from Wiltshire to the south of the Kentish coast in one direction, and to the northern point of the Norfolk coast in another; and it is open to the ocean upon the Essex, Suffolk, and

Norfolk coasts, which shew sections of its contents.

The numerous wells which have been dug in the neighbourhood of London, and the canals, tunnels, and other excavations and public works which have been carried on, have lately made us acquainted with many curious facts respecting the contents of this basin. Several specimens of the fossils found in it are preserved in the geological collection of the Institution; and in the descriptive Catalogue, (page 42) will be found some further observations respecting it.

It deserves remark, that all the bones of viviparous land quadrupeds have either been found in the uppermost fresh water deposits, or in those alluvial formations of the ocean, which appear to have been the result of violent transportations of materials, rather than of quiet depositions: so that it is probable these animals began to exist during that state of the world which preceded the last inundation of the sea.

The Palæotheria, Anaplotheria, and other unknown genera described by Cuvier, are found in the lowest parts of the upper fresh water formation, placed immediately under the upper marine formation. Some oviparous quadrupeds and fresh water fish are found along with them, and they are covered by alluvial deposits containing marine relics.

The unknown or extinct species belonging to known genera, such as the mastodon, elephant, hippopotamus, and rhinoceros, are never associated with the more ancient or extinct genera, but are discovered usually in the sea water deposits; and the bones of species resembling those that now exist, are found upon the sides of rivers, or in the bottoms of ancient lakes and marshes, or in peat bogs, or in caverns and fissures of rocks, and in consequence of their superficial situation they are generally much injured.

In the month of November, 1816, a cavern was discovered in the limestone rocks near Plymouth, by Mr. Whitby, in which were found the bones of the rhinoceros, embedded in clay, and in a very high state of preservation; they were sent to Sir Joseph Banks, in whose possession

I saw them. If this cavern has no outlet, and if the bones, as supposed by Mr. Whitby, were really contained in a large nodule of clay, buried in the solid rock, many of our recent geological theories must be subverted; this however is extremely unlikely; and the cavern filled with clay, will probably be found of much more recent date than the strata in which it occurs.

Of a very singular and important series of rocks, I have yet made no mention. They occur indiscriminately in primary and secondary countries, and are not less varied in their characters and aspects, than in their situation. These are the TRAP rocks of the Wernerians, and the WHINSTONES of Dr. Hutton. They include the rocks called *Greenstone*, *Basalt*, *Amygdaloid*, and *Toadstone*, and are distinguished into primary, transition, and floetz traps, by the school of Freyburgh.

By the term *Greenstone*, we mean a compound of hornblende and felspar, differing extremely in its appearance, being sometimes so fine grained, as to appear homogeneous ; at other times presenting distinct and often large crystals of hornblende.

Basalt is always a homogeneous rock, and abounds in black oxide of iron. Greenstone is met with in many parts of England, immediately upon granite, and primary rocks ; and it assumes the character of its neighbours, breaking into large blocks and masses of very irregular appearance. In this state it is seen in Cornwall, at the Lizard Point. Upon the north side of the Welsh mountains a chain of greenstone follows the slate, which in some places is columnar, as upon Cader Idris, and it forms a singular concavity near the summit of that mountain, very like the crater of a volcano. In Derbyshire, these rocks are among the transition series of Werner. They form strata, and fill cavities in the limestone. In coal-fields they constitute dykes or veins, and among secondary strata, they are seen in sandstone at Edinburgh ; and upon the coast of Antrim, they are incumbent upon, and alternate with chalk. Cavities in basalt are often filled with calcareous spar, zeolite, and agate nodules.

The common observer, to whom a piece of basalt is presented, would presently announce it to be the produce of a volcano. and the analogy between it and lava is most striking. This alone would justify us in concluding that whinstone is the produce of fire. But the Huttonian hypothesis as applied to its origin becomes much more satisfactory, when we contemplate the effects produced upon the strata into which it has been thrown, or upon the substances in its vicinity. Thus the sandstone of Salisbury Crag, near Edinburgh, is broken, indurated, and even apparently fused by its irruption. The soft white limestone of the county of Antrim, where in contact with the basaltic dyke, is hardened and rendered crystalline, like marble and calcareous spar: and the coal in the same county is coaked as it were, where touched by the whinstone At the same time the dykes themselves bear evident marks of igneous fusion. They are more regularly crystallised in the centre than upon the surface, an effect which may be well referred to the different rates of cooling, in the melted mass, and which may even be imitated artificially with the slag of an iron furnace.

Perhaps the most remarkable phenomenon concerning basalt, is its occasional columnar structure, an appearance which lava sometimes assumes. Upon this subject, Sir James Hall's experiments are of extreme interest, and when conjoined with those of Mr. Watt, produce a further and indeed irresistible evidence in favour of the igneous origin of basalt.

In accounting for the humid origin of basalt, the Neptunists refer to the columnar cracking of clay, mud, starch, &c. during drying; and in this they fancy an analogy to basaltic columns; but in these cases there are always chasms and vacuities produced by the shrinking of the mass; whereas the columns of basalt are so closely connected, that the thin blade of a knife can scarcely be thrust between them. Upon the whole, the Huttonian theory may be considered as nowhere more free from objections, than where it applies to basalt; while the hardening, contortions, and breaking of the strata by whin dykes, and the numerous analogies of basalt and lava, are to the Neptunians paradoxes which admit of no solution.

Of columnar basalt the British dominions present the noblest specimens in the known world. Upon the coast of Antrim in Ireland, massive and columnar basalt is seen in all its varieties: the former abounding in deep and lofty caverns, the latter presenting various façades to the ocean. The Giant's Causeway consists of three piers of columns, which extend some hundred feet into the sea. It is surrounded by precipitous rocks, from two to four hundred feet high, in which there are several striking assemblages of columns, some vertical, some bent or inclined, and some horizontal, and as it were driven into the rock. Bengore, which bounds the Causeway on the east, consists of alternate ranges of tabular and massive, with columnar basalt. But amongst the various and grand objects on this coast, Pleskin is perhaps the most striking; it presents several colonnades of great height and regularity, separated from each other by tabular basalt; and at Fairhead there is a range of columns of from ten to twenty feet in diameter, and between two and three hundred feet high, supported upon a steep declivity, and forming a terrace which towers nearly six hundred feet above the waves beneath. He who would really see the sublime, should visit this stupendous promontory.

Another basaltic district, which I am inclined to regard as exceeding the former in magnificent peculiarities, is that which presents itself in sailing down Loch Nagaul in Mull, towards the Isle of Tiree. The coast of Mull upon the right and left, exhibits the step like appearance of basaltic rocks in great perfection, and has fine caverns and columns; the islands of Ulva and Gometra rise with the abrupt and irregular pre ipices common to this formation. The Treshamish Isles exhibit columnar and massive basalt, and in the midst of this curious panorama, Staffa presents itself. The columns which are from sixty to ninety feet high, are approached by a fine causeway, rising gradually from the deep, and they appear to support an immense weight of tabular basalt. The pillars are perpendicular, inclined, and in places extremely curved; and in the cave of Fingal, the ranges of columns extend, in long perspective, into the interior of the rock, presenting a scene of such unrivalled grandeur, as hitherto to have foiled all attemps of the poet to describe, or of the painter to represent.

LECTURE VI.

Metallic Veins.—Theories of their Formation.—General causes of the Decomposition of Rocks.—Purposes fulfilled by their decay.—Volcanoes.—Conclusion.

THE object of the preceding Lectures has been to explain the succession of strata over the globe, to describe the materials of which they are constituted, and to point out their aspects, gradations, and peculiarities, when existing as mountain masses. I have endeavoured likewise to put you in possession of the leading facts which belong to the theories of the earth, to shew in what they excel, and where they are deficient, and to pursue the arguments of the inventors, as far as these have led to useful investigation, or have disclosed new views of the œconomy of Nature.

Besides the veins of lapideous substances, the fissures filled with debris and rubbish, the dykes, the beds of salt, and the fields of coal, there are diffused through the strata a variety of other treasures, among which the metals are of the utmost interest and importance. By the term *Mineral Vein*, we mean a separation in the continuity of a rock of determinate width, but extending indefinitely in length and depth, filled with metallic ores, and crystalline substances differing from the rock itself.

Nearly all rocks are occasionally thus traversed, but the middle series are those in which metals are most abundant. In Cornwall, for instance, tin occurs both in the granite and slate; but it is most abundant in the latter, and the vein occasionally runs between the two rocks, so that one wall consists of granite and the other of slate. The metal is often separated from the rock by thin layers of clay, or of stony materials called *Deads*, which also intermix with the ore, and form its *Gangue* or *Matrix*.

The richest metallic veins run, without exception, east and west. Those which run north and south being usually filled with stony materials. The latter veins appear of posterior date to the former, for they often intersect them, throwing them out of their regular course; generally, a few inches only, east and west, but many fathoms north and south. These *Cross courses* generally interfere with the treasures of the metallic vein, though when solid, they are sometimes of great service in keeping out water.*

The extent to which veins may be pursued, is extremely various, and depends much upon accidental circumstances. Sometimes a cross course cuts the vein, and puts an end to the miner's hopes, he being unable to discover its continuation after such interruption; sometimes the depth of the vein becomes so great, that it cannot be prudently pursued; sometimes a rich lode of metal suddenly disappears, or vanishes into thin strings, which though often quite lost, occasionally reunite into a good vein or bunch of metal. So that taking all these circumstances into account, between two or three miles is usu-

* This was at one time remarkably the case in the celebrated Maudlin mine, near St. Austle, in Cornwall.

ally the utmost extent to which a vein has been pursued.

Veins vary in width from an inch or two to thirty or forty feet, but the middle sized veins are usually most prolific, the larger becoming relatively poor. The influx of water was formerly an insuperable impediment to the pursuit of a vein, and remains now a serious and expensive obstacle to mining. Formerly many veins in Cornwall were only worked for tin, which at greater depths have lately yielded abundance of copper; but in Cornwall, copper is never found without water, and all the mines of that metal require drainage, by engines* or other means.

Concerning the original formation of metallic veins, there has been considerable collision of sentiment among geologists; but two circumstances seem sufficiently obvious; one, that they are of later date than the containing strata, that they are not contemporaneous; and the other, that

* The engines in Cornwall often throw off a thousand gallons per minute, night and day.

their contents have been in a fluid state. The former position is indicated by their intersecting different strata; the latter, by the crystalline forms of the substances they contain. The Neptunists tell us that veins have been filled by metallic and lapideous solutions flowing in from above, but they do not inform us of the nature of the solvent which held the different bodies they present; nor can we guess why its contents are deposited exclusively in the vein, and not found upon the adjacent surface.

The Plutonists consider veins as filled from below, by the injection of matters in igneous fusion; and in the shifting, breaking, and dislodgement of the strata, they read the force with which these operations have been performed. The validity of hypotheses is only to be estimated by their accordance with facts, and although there be many inexplicable phenomena attending metallic veins, yet the nature of their contents is such as to favour the igneous hypothesis, and to lead to the belief, that fire, not water, has been the grand solvent of which nature has here availed herself. That the metals have passed from the fluid to the solid state, seems sufficiently obvious from their crystalline form, and it is much more probable that they should have been liquified by heat, than by any other solvent.

Sulphur is very commonly found united to metallic bodies, and the greater number of metallic ores contain that element. Such compounds are easily produced by the artificial agency of fire, but with great difficulty by any other process.

A very curious fact in the history of veins is, that they are of different dates, for one vein often intersects another, and we are thus enabled to judge of their relative ages. In the county of Cornwall, one of the richest mining districts of the world, we observe some remarkable circumstances of this kind. Where a copper and a tin vein, for instance, meet, the former always cuts through the latter, and generally throws it out of its old course, greatly to the distress of the miner, who sometimes cannot find its continuation, or at least is put to much difficulty and expense to do so. It appears, therefore, that tin veins are invariably older than those of copper. Sometimes, as in Derbyshire, the metallic ores lie in large longitudinal cavities, called *pipe veins*.

In searching for veins of the useful metals, there are certain indications of which the experienced miner sometimes profitably avails himself. Thus, a green earthy matter is a good symptom in a tin mine; a brown ochrey earth and compact iron pyrites, are regarded as favourable omens in a copper mine.

Detached pebbles of ore, or fragments of vein stones have sometimes led to the riches of the vein, and tin has especially been thus discovered in Cornwall.

The miners, though a shrewd class of people, are often preyed upon by the most vulgar superstition, and many ancient absurdities are still retained, and cherished in their art. The divining rod and other oracles are yet consulted; genii are said to preside over the mines; and he who inadvertently whistles when below ground, breaks the spirits of his companions for the day, though freely permitted to indulge his musical disposition in the form of a song.

In older mineralogical works we read much upon these and other subjects. Flames of light have been described as playing over a district which afterwards has been found to contain subterranean riches, and this may have arisen from the good electrical conducting powers of the vein. The waters issuing from the soil sometimes hold metallic salts in solution, and repositaries of the metals have been discovered by circumstances of this kind. Copper veins tinge waters blue, and a piece of grease put into them becomes rapidly stained of that colour. There is no popular notion more common than that metals grow in the veins; an idea which may very probably have originated from observing the depositions of one metal by the introduction of another into its solution, as when silver is precipitated by the introduction of a plate of copper into its solution, or copper by iron.

Districts rich in the metals are generally barren, and seem peculiarly dreary and desolate to the traveller. This partly arises from the nature of the strata, partly from the heaps of rubbish and hills of stone thrown upon the surface, and partly from the operations carrying on in the vicinity, being inimical to vegetation. The high road through Cornwall, especially near Redruth, is an excellent specimen of this kind of country, while, at the same time, the romantic beauty and luxuriant vegetation of many parts of that county, and of Devonshire, prove that exterior cultivation is not always incompatible with internal riches. The neighbourhood of the Parys mountain in Anglesea, is singularly marked by sterility and gloominess. The soil, naturally unproductive, is rendered more so by the poisonous waters that traverse it, and the sulphurous vapours that float around. There are not only no shrubs and trees, but the barrenness is unrelieved even by a single blade of grass, or the rusty green of a hardy lichen.

Having now added to the enumeration of the series of rocks which present themselves as the crust of our globe, a brief account of the manner in which they are penetrated by metallic veins, I propose, in conclusion, to consider the changes they are undergoing, and the effects of which they are productive in the economy of the globe.

In the progress of these Lectures I have hinted at the relative permanence and durability of the different kinds of rocks, and it has been found that the unstratified or primary substances are least acted upon by the elements; that these have retained their great and pristine elevation, while the secondary strata have been washed from their sides and summits, whose rugged and abrupt outline records this devastation. Every one who views the mountain side strewed with immense blocks of materials transported from distant summits, and discovers the dells and vallies filled with fragments and pebbles of the neighbouring rocks, will allow that a constant system of disintegration and decay is here carrying on; but the geologist, not content with the mere observance of the fact, will endeavour to trace it to its source, and follow it up to its ultimate effect.

The change of temperature to which the earth's surface is constantly submitted, is one great cause of the slow destruction of its most solid and durable constituents, and when to this is added the gigantic powers with which water in becoming ice, opposes the obstacles to its expansion, we have an agent nearly resistless.*

Masses of rock thus loosened from their original beds, become new and powerful instruments of destruction; they roll down the precipices, wearing themselves and

* The fissures that occur between the blocks and masses of the granites, porphyries, and similar rocks, become filled with water which in the act of freezing expands so as slowly to remove them from each other, their edges and angles become thus open to the attacks of the weather, and by a slow dislodgement they fall into the vallies or rivers, or are at once cast into the ocean. Where the materials are of a more yielding and frangible texture this destruction is proportionally rapid and the influence of the weather upon slate mountains, is often such as to produce hills of fragments at their feet; the softer substance of the secondary and horizontal strata is of course yet more easily and quickly degraded.

the surface that bears them, and if near the sea, or carried thither by rivers, they become "a part of the mighty artillery with which the ocean assails the bulwarks of the land;" they are impelled against the coasts from which they break off other fragments, and the whole thus ground against each other, whatever be their hardness, are reduced to gravel, the smooth surface and rounded masses of which are convincing proofs of the manner in which it was formed. It is by operations of this kind, not performed in a day, but in ages, that nature has indented and carved out the earth's surface, that the rivers seem to have cut their own beds, that the land is undergoing gradual demolition, and that the materials which we have elsewhere considered as consolidated at and elevated from the bottom of the ocean, are gradually restoring to the parent deep. These are mechanical agents, but they are not unassisted by the chemical energies of matter; and in this respect, the solvent powers of water may be contemplated as effecting most important changes.

By impregnation with carbonic acid, water acquires a great solvent power over carbonate of lime, and in trickling through such strata becomes saturated with it, and on exposure again deposits it in consequence of the escape of the gaseous solvent: it is thus that the stalactitical concretions of limestone caverns are produced, as in the Fluor Mine, and Peak cavern of Derbyshire; and in many cases, the once empty chasms are entirely choaked up by this sparry deposit. The power of incrustation thus possessed by some waters, is such as rapidly to cover extraneous bodies thrown into them with a calcareous coating, of which the petrifying spring of Matlock furnishes a good example.

The sands upon flat coasts are sometimes agglutinated by this action of water so as to produce a new rock, or as the Wernerians would call it, a new formation. This has probably been the case with the stone in which the *Galibi*, or human skeletons of Guadaloupe are found, and the process is constantly going on upon the coast of Cornwall, in the parish of St.

Columb, where the water having percolated the neighbouring rocks becomes slightly carbonated and ferruginous, and thus serving as a cement to the sand, produces a hard stone, which is used as a building material, and for making cattle troughs. In the walls of some of the oldest churches in Cornwall, as in St. Burian, Gwithian, Crantock, Cubert, &c. are large masses of this *sandstone* which has thus long resisted decomposition. When water is hot, and slightly alcaline, it dissolves siliceous earth, as shewn by the deposits of the Geysers or boiling fountains of Iceland.

Some rocks suffer in consequence of the action of air and water upon the black oxide of iron which they contain, and which in passing into the state of brown oxide occasions a crumbling of the mass. Much of the soil upon the coast of the county of Antrim in Ireland, is thus derived from the decomposition of basalt, which, however, in other cases singularly resists change, as in Staffa, where the columns, though exposed to the violence of the ocean, retain a sharp angularity and black colour. These differences depend upon the degree of induration of the basalt.

Rocks containing alcali seem often to decompose rapidly in consequence of the loss of that ingredient. The quick disintegration of much of the Cornish granite is well known, and it furnishes a valuable material for the manufacture of pottery. The felspar of this granite contains a considerable portion of potash, but the white earth into which it is resolved yields no traces of it.

The chemical agencies of different bodies presented to each other in the strata, are also often connected with the production of entire new substances. Thus the decomposition of pyrites in chalk produces sulphate of lime; in aluminous slate it gives rise to the production of alum; and in the cliffs at Newhaven, on the Sussex coast, a very curious series of changes is going on.

A stratum of marl containing decomposing pyrites lies upon the chalk, which gives rise to the formation of sulphate of alumine; this is decomposed by the chalk; and aluminous earth, selenite, and oxide of iron are the results.

Thus, by mechanical operations and chemical changes, sometimes separate and sometimes united, the rugged peaks and abrupt precipices are gradually wearing and softening down, and giving rise to rounded summits, gentle slopes, and habitable surfaces. The detritus so produced is carried by rills, and brooks, and rivers towards the low lands, where it is deposited; or it is transported towards the sea, where it forms bars and islands at the mouths of rivers; or it is employed in levelling uneven surfaces and filling cavities and basins, as where the rivers are broken in their course by the intervention of lakes, all of which are filling up, as may be learned even by hasty inspection. This is no where more conspicuous than in the waters which adorn the scenery of Westmoreland and Cumberland, especially Derwent water, at the Borrowedale extremity of which the meadow is annually increasing, and adding to the circumjacent field; and the examination of the bank between Derwent and Bassenthwaite shews that the two lakes were once united, and that the present separation, is alluvial matter, or a bar thrown up by the concurrent streams of Newland's water, on the west, and the Greta on the east. The filling up of lakes until they ultimately become merely a part of the river that now traverses, but once fed them, is too obvious to require further illustration; it is the reason why the stream which has its exit from a lake is generally clear, while the torrents which supply it, are loaded with matters in minute mechanical division. While the destructive agencies of the elements are thus called into action, for the production and increase of habitable surface, we observe other causes tending to the same effect, and none more wonderful than the incessant labours of those insect tribes which collect and accumulate solid matter from the ocean, and form the rocks of coral, common in the seas of warm climates.

But the most striking sources of decay and reproduction are those dependent upon volcanic phænomena.

The form of volcanic hills is usually conical, of which the outline of the bay of Naples presents a fine panorama. One of its hills serves to give some idea of the vast powers of the subterranean agents; it is about one thousand feet high, and three miles in circumference, and was raised in 1538 in a single night.

In June 1811, a volcano was discovered in the sea off St. Michael, and it formed an island about a mile in circumference.

To describe the phænomena of volcanic eruptions with all attending circumstances would be foreign to the purpose of these Lectures, but as the same causes may have been active in producing other geological phænomena, it becomes right to mention the subject.

Until lately the cause of volcanic fire was referred to sulphur, coal, and other common inflammable matters which were supposed to be burning in immense masses within the earth, and thus to give rise to the tremendous explosions and ejections of lava and stones attending the eruption; but the products ill accord with such an explanation. Earthy, alcaline, metallic, and stony bodies united, form the lava, and steam and hydrogen gas accompany its throwing forth, and as the products of combustion always have a reference to the combustible, such matters were not likely to be produced from sulphur or coal.

The brilliant chemical discoveries made some years since by Sir H. Davy, have enlightened this as well as every other branch of chemistry, and from them we may deduce a very adequate solution of the problem of volcanoes, for we have only to suppose the access of water to large masses of those peculiar metals which constitute the alcaline and earthy bases, and we are possessed of all that is wanted to produce the tremendous effects of earthquakes and volcanoes; for what power can resist the expansive force of steam, and the sudden evolution of gaseous fluids, accompanied by torrents of the earths in igneous fusion, which such a concurrence of circumstances would give rise to, and which are the actual concomitants of volcanic eruptions?

From the same source the Huttonian theory derives great additional plausibility, for its feeblest parts were those which related to the required expansive forces, to the intense continuance of heat, to its occcasional increase and decrease, and to the existence of a species of fuel adequate to the various effects that have been described. The metals of the earths are equal to the production of all these complicated and apparently incompatible effects, and these and water are the sole agents required.

It is unnecessary that I should here recapitulate the Plutonian and Neptunian evidence. The former is that which I have embraced as most plausibly accounting for the phænomena, as least at variance with facts, as least hypothetical, as the best entitled to the appellation of a theory of the earth; at the same time, I have not intentionally suppressed any thing favourable to the opposite side; to that, which I profess *not* to espouse. Nor would I be deemed assentient to every clause of the Huttonian doctrines. Theorists always fly to extremes; and he that would profit by their opinions, must submit them to the balance, reject those that are light, and often recoin the others. "God forbid, (says a celebrated writer) that man, whose teacher is the whole circle of nature, should be regarded as a mere lump of wax, upon which any Professor may stamp at pleasure, his own conceited image."

It appears then that the terrestrial changes going on around us, both rapid and gradual, are subservient to the most beneficial effects, and that by operations apparently destructive, nature renovates her powers: from the decay of animated beings we have elsewhere deduced similar conclusions, and in inanimate nature, we now read the same great and exalted truths; we learn that the Author of nature has not given laws to the universe, which, like the institutions of men, carry in themselves the elements of their own destruction, but that His works are preserved in unchangeable perfection, and as it were in eternal youth. If there be any part of natural knowledge calculated to awaken in us the most profound sense of the excellence and perfection of Nature's works, it is surely in the subjects that have now been before us. That person is little to be envied who, beholding the immensity of the universe, and marking the majestic simplicity by which its operations are conducted, does not feel awakened to a higher species of being, and admitted into nearer intercourse with the Author of nature. In short, it is impossible to pursue knowledge without mingling with it the best sentiments of devotion, or to perceive the laws of Nature without at the same time discerning the hand of the Lawgiver. Thus in every age and country, " the evidences of religion have advanced with the progress of true philosophy; and science, while she raises a monument to herself, at the same time erects an altar to the DEITY."

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