THE

WONDERS OF GEOLOGY;

OR,

A FAMILIAR EXPOSITION

OF

Geological Phenomena.

BY

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Volcanic Island in the Mediterranean.—Page 839.

"Every rock in the desert, every boulder on the plain, every pebble by the brook-side, every grain of sand on the sea-shore, is replete with lessons of wisdom to the mind that is fitted to receive and comprehend their sublime import."

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"Though Nature is now no longer, as it were, a sealed book, but lies more transparent and less veiled to the eye, the moral and material universe still remains to us by no means disenchanted of its beauty, and of its religion; for the mystic ground of things unknown is carried only a remove beyond its former boundary, and to a higher sphere."

Dr. Verity.

THE

WONDERS OF GEOLOGY.

LECTURE V.

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1. ZOOLOGY OF THE CHALK.—The examination of the Cretaceous and Wealden formations has afforded an instructive exposition, not only of the nature of oceanic and river deposits in general, but also of the condition of animated nature at the close of the geological cycle which comprises the secondary epochs. It will therefore be expedient in this stage of our inquiry to consider the general features of the animal kingdom during the periods embraced in this review.

In the ocean-bed of the chalk we find vestiges of all the principal groups of existing marine organisms; comprising many genera of the Shark family—viz. species of Cestracion, Acanthias, Lamna, Galeus, &c.; with fishes related to the Chimæra, Salmon, Smelt, Pike, Ray, &c.: in fact, the leading types of the majority of the fishes that inhabit the present seas.* The Cephalopoda and Echinodermata or Sea-urchins, were profusely developed; Star-fishes, Encrinites, and other Radiaria; crustaceans allied to the Crab, Lobster, Shrimp, Prawn, &c.; univalve and bivalve mollusca; and innumerable multitudes of Foraminifera;—all these forms of animal existence have left enduring memorials of their presence in the seas of those remote ages. And although we have likewise proof that numerous extinct genera, together with others now of excessive rarity, swarmed in prodigious numbers in the cretaceous ocean; and negative evidence that the Cetacea, as the Whale, Porpoise, Seal, &c., were not among its inhabitants, yet the diversified types of animated beings whose relics are entombed in these strata, show that the waters of the deep possessed the same general conditions, and maintained the same relations with the atmosphere and with light, as at the present time.

The most remarkable peculiarity in the zoological features of the Chalk, relates to the predominance of Reptiles; for, with the single exception of a lizard belonging to the family of the *Iguanidæ*, which inhabits certain parts of the sea-coasts of South America,† the Chelonians or Turtles, are the only known existing marine animals of this class. But the cretaceous sea was tenanted by several saurians of considerable magnitude; namely, the Mosa-

* See the chronological table in M. Agassiz's Recherches sur les Poissons Fossiles, tome i.

† The *Amblyrhynchus cristatus* of the Galapagos Islands: see Mr. Darwin's Journal, in the Colonial Library, p. 385.

saurus (p. 311), Polyptychodon (p. 354), Ichthyosaurus,* Plesiosaurus, and others, of which imperfect vestiges only have been obtained.

Of the terrestrial fauna and flora, the evidence to be derived from deep sea deposits must of course be scanty. We have however proof that the then dry land was clothed with forests of pines, and that ferns, and plants of the cycadeous tribes, formed the prevailing vegetation; and that the country was inhabited by Iguanodons, Pterodactyles, and other reptiles.

2. Zoology of the Wealden.—From data of a like nature, we learn that during the deposition of the Wealden, there was an extensive region traversed by streams and rivers swarming with fishes, crustaceans, and mollusca, of extinct species, but belonging to the same principal types as those which inhabit the fresh waters of tropical climates, under similar conditions: and that then, as now, fluviatile turtles and crocodilian reptiles tenanted the swamps and marshes.

Of the inhabitants of the land, we have more ample information from the relics engulfed in the deltas and lacustrine sediments, than could be afforded by deposits accumulated in the depths of the ocean, and far from the regions whence they were derived.

Colossal herbivorous and carnivorous lizards, differing essentially in their organization from all existing reptiles, and of which no vestiges have been discovered in any strata newer than the Chalk, were the principal terrestrial vertebrata of the Wealden epoch. These, together with a few flying reptiles, and lizards of small size, and probably some kinds of wading birds, constituted the entire fauna of the regions which furnished the materials of this for-

* A new species of Ichthyosaurus, having the fangs of the lower teeth curved, (*I. campylodon*), has lately been found in the Lower-Chalk of Cambridgeshire: see London Geological Journal, No. I. p. 7.

mation. The flora consisted chiefly of coniferous trees, ferns, cycadeous plants, cypresses, and a few unknown, but apparently related forms. In fact, the islands and continents of the Wealden and Cretaceous epochs, appear to have possessed the same zoological and botanical characters. Here then we have the first glimpse of extensive regions almost exclusively inhabited by enormous reptiles: for though the leaves and fruits of delicate plants, and the fragile bones of birds and flying reptiles, and brittle shells with their ligaments and epidermis remaining, are found imbedded in the sediments of the rivers and seas, not the slightest traces of any mammiferous animal have been discovered! I forbear to comment in this place on this extraordinary fact, of which our examination of the tertiary formations afforded no intimation. We have now approached the *Age of Reptiles;*—that geological epoch, in which the earth swarmed with enormous oviparous quadrupeds, and the air and the waters alike teemed with reptilian forms.

3. Site of the country of the Iguanodon.—Before we pass to the investigation of the older secondary formations, I would briefly reconsider the question as to the geographical position of the principal tracts of country during the deposition of the Wealden and cretaceous strata;—whether England was then dry land, and enjoyed a tropical climate; and whether turtles, crocodiles, and gigantic lizards, here flourished amid groves of tree-ferns, and other productions of intertropical climes; or, on the contrary, whether the country of the Iguanodon was situated far distant from the area now covered by its spoils?

The unequivocal marks of transport which, as we have seen, the fossils so generally exhibit, seem to demonstrate that the reptiles and terrestrial plants could not have lived and died in the regions where their relics are imbedded: for with the exception of the beds of river shells and crustaceans, and the plants which indicate a lacustrine condition, the organic remains bear indisputable marks of having been transported from some remote country, by a river, or powerful flood of fresh-water.*

The specimen of the Hylæosaurus, (*ante*, p. 435,) throws light on this question. Many of the vertebræ and ribs are broken and splintered, but the fragments remain near each other: and though the bones are, more or less, displaced, yet they lie in situations bearing some relation to their natural positions. These facts demonstrate that the carcass of the animal must have been contused and mutilated, and that the dislocated and broken parts were held together by the muscles and integuments. In this state the headless trunk must have floated down the river, and at length have sunk into the mud of the delta, where it formed a nucleus, around which the stems and foliage of ferns and cycadeous plants accumulated, and river shells became intermingled in the general mass. Here then we have unequivocal evidence of the body of a terrestrial reptile having been transported from a considerable distance by a stream or current of fresh water; for not the slightest indication of marine detritus can be traced in the deposits in which it was imbedded. The country where this animal lived and died must therefore have been situated very far from the spot where its fossil remains were entombed.

An eminent geologist has the following remarks on this subject. †

* The upright trees of the Isle of Portland present an apparent exception; but this forest may have grown on an island, very remote from the mainland inhabited by colossal reptiles.

† Mr. Lyell. Elements of Geology, Second Edition, vol. i. p. 432.

"If it be asked where the continent was placed from whose ruins the Wealden strata were derived, and by the drainage of which a great river was fed, we are half tempted to speculate on the former existence of the Atlantis of Plato; for the story of the submergence of an ancient continent, however fabulous in history, may be true as a geological event. Its disappearance may have been gradual; and we need not suppose that the rate of subsidence was hastened at the period when the displacement of a great body of fresh water by the cretaceous sea took place. Suppose the mean height of land drained by the river of the Wealden estuary to have been no more than 800 or 1000 feet: in that case, all except the tops of the mountains would be covered as soon as the fundamental oolite, and the dirt-bed were sunk down about 1000 feet below the level which they occupied when the forest of Portland was growing. Towards the close of the period of this subsidence, both the sea would encroach, and the river diminish in volume, more rapidly; yet in such a manner, that we may easily conceive the sediment at first washed into the advancing sea, to have resembled that previously deposited by the river in the estuary. In fact, the upper beds of the Wealden, and the inferior strata of the Greensand, are not only conformable, but of similar mineral composition.

"It is also a remarkable fact, that the same *Iguanodon Mantelli*, which is so conspicuous a fossil in the Wealden, has been discovered in the overlying Kentish-rag, near Maidstone. Hence we may infer, that some of the Saurians which inhabited the country of the great river, continued to live when part of the country had become submerged beneath the sea. Thus in our own times, we may suppose the bones of alligators to be frequently entombed in recent fresh-water strata in the delta of the Ganges; but if part of that delta should sink down so as to be covered by the sea, marine formations might begin to accumulate in the same space where fresh-water beds had previously been formed; and yet the Ganges might still pour down its turbid waters in the same direction, and transport the carcasses of the same species of alligator to the sea; in which case their bones might be included in marine as well as in subjacent fresh-water strata."

4. LITHOLOGICAL STRUCTURE OF THE IGUANODON COUNTRY.—The nature of the rocks and strata of which the country of the Iguanodon was composed is also a subject of considerable interest; and from the first moment that the fluviatile origin of the Wealden suggested itself to my

mind, to the time when I was compelled by ill health to quit the field of my early researches, I lost no opportunity of obtaining data by which the problem might be solved, and carefully examined the pebbles and boulders, and the fine detritus as well as the coarser materials of which the Wealden beds are composed.

My lamented friend, the late Mr. Bakewell, kindly afforded me his valuable aid in determining the nature of the rocks whence the debris was derived; but the materials were too scanty to throw any satisfactory light upon the inquiry. In my "Fossils of Tilgate Forest" a bed of conglomerate, near Cuckfield, is described as containing pebbles of white, yellow, pink, and mottled quartz, jasper, flinty-slate, and indurated sandstone: and from this deposit I expected to obtain more satisfactory information than from the fine detritus of which the sands, sandstones, and clays consist. But with the exception of small pebbles of rock crystal,* the substances above mentioned comprise all the transported minerals that have come under my observation. The abundance of micaceous particles in many of the sands and sandstones, and the prevalence of argillaceous and arenaceous deposits, seem to indicate a region in which were primary rocks, and strata of sandstone and clay; for the quartz pebbles, and the micaceous sands and clays, may have been derived from decomposed granitic and felspathic rocks. I have never seen any extraneous fossils either in the Wealden or Chalk, with the exception of a rolled fragment of coniferous wood, which, from its state of mineralization, there is reason to conclude is from the oolite.†

* Small rock crystals are often found in the sandstone near Tunbridge Wells, and are cut and set in rings and brooches by the lapidaries of that town.

† This specimen was found by my friend Henry Carr, Esq. C.E., in a block of white chalk from a railway cutting near Epsom. See

The observations of Dr. Buckland on this problem entirely accord with the result of my own investigations.

"The general absence of pebbles shows that the lands were distant whence the fine particles of sand and clay were transported. It is not probable that the materials of the Wealden formation have been derived in any great degree from the detritus of the oolitic series, because in such case we should find among them an admixture of pebbles of oolite, none of which have yet been noticed,—we should be inclined rather to look for the lands whence the strata have been supplied, either in Devonshire or Cornwall, on the west; or in the nearest primary and transition mountains of the Continent, viz. in Normandy and Brittany, on the south-west; or in the forest of Ardennes, on the south-east."*

Of the seaward extension of the delta of the Iguanodon river, no certain indications have yet been obtained: but it is evident that there must have been intercalations of the detritus and organic remains of the land and fresh-water, with those of the sea into which the mighty stream discharged its waters; and there can be no doubt that sooner or later these fluvio-marine wealden strata will be discovered.

5. Medial Secondary Formations.—In accordance with the chronological arrangement (p. 200), I proceed to the consideration of the antecedent or medial group of the secondary formations, namely the *Oolite*, *Lias*, and *Trias*. As a whole, the series consists of alternations of clays, marls, limestones, sands, and sandstones, abounding in marine exuviæ, and which have evidently been deposited in the basin of a sea or seas. With these strata are intercalated in some localities beds of fluvio-marine detritus, in which vestiges of land animals and plants are imbedded.

The fossil remains of the inhabitants of the sea comprise a prodigious number of zoophytes, crinoidea, mollusca,

Geology of the Isle of Wight, p. 193. Dr. Fitton mentions having found a rolled ammonite in the Wealden.

* Geol. Trans. vol. iii. new series.

cephalopoda of extinct forms, crustacea, fishes, and reptiles; and the plants belong to many species of fuci, algæ, &c.

Those of the land consist of such as were transported into the ocean by rivers and currents, namely, trunks and branches of coniferous trees, cycadeous plants, ferns, &c.: sometimes in the state of lignite, and coal. The animal relics are principally of insects, with bones and teeth of numerous reptiles; and of two or three genera of small *terrestrial mammalia*. Evidence is thus afforded of the existence of countries clothed with a luxuriant vegetation, and inhabited by a prodigious number of reptiles, and a few warm-blooded quadrupeds.

I shall also comprise in this Lecture a notice of the Permian formation, that the Carboniferous system may be considered in a separate discourse.

6. General view of the Oolite and Lias.—The Oolite formation may be described as consisting of three principal argillaceous, and of an equal number of calcareous deposits. The leading subdivisions of these strata as they occur in England, and the names by which they are generally distinguished, are expressed in the following table. The Lias is included, for though in conformity with the usual geological classifications this group of strata is placed as a separate formation in the synopsis (p. 202); we shall find it convenient, and I believe more in accordance with the origin and nature of the deposits, to comprise it in a general survey of the Oolitic or Jurassic system.*

* In the Map, Pl. I. vol. i. the Oolite and Lias are denoted by the same colour and number (4).

THE OOLITIC OR JURASSIC SYSTEM.

OOLITE.

Upper oolite of the Isle of Portland, Wilts, Bucks, Berks, Oxfordshire, &c.	1. *Portland oolite;*—limestone of an oolitic structure, abounding in ammonites, trigoniæ, &c., and other marine exuviæ; green and ferruginous sands; layers of chert; drifted wood, cycadeous plants; bones of turtles and lizards. 2. *Kimmeridge clay;*—blue clay, with septaria and bands of sandy concretions; marine reptiles, fishes, shells, corals, and other organic remains.
Middle oolite.	1. *Coral oolite,* or coral-rag;—limestone composed of corals, with shells and echini; coral reefs. 2. *Oxford clay;* with septaria; abounding in fossils; beds of calcareous grit, called Kelloway-rock; also full of shells, corals, and other organic remains.
Lower oolite. Gloucestershire, Oxfordshire, and Northamptonshire.	1. *Cornbrash;*—a coarse shelly limestone. 2. *Forest marble;*—layers of fissile arenaceous limestone—coarse shelly oolite—sand, grit, and blue clay. 3. *Great oolite*—calcareous oolitic limestone and freestone; upper beds, aggregates of shells. *Stonesfield slate;* containing leaves and fruits of palms, cycadeæ, and other land plants; insects, reptiles, and *mammalia.* 4. *Fuller's earth beds;*—marls and clays, with fuller's earth—sandy limestones with shells. 5. *Cheltenham* or *Inferior oolite;*—coarse limestone—conglomerated masses of terebratulæ and other shells—ferruginous sand, and concretionary blocks of sandy limestone, and shells.
Lower oolite of the Yorkshire coast.	1. *Cornbrash;* a thin bed of rubbly limestone; which in many parts is a mere aggregation of shells and other fossils. 2. *Sandstones and clays,* with land plants; *thin coal and shale;* calcareous sandstone and shelly limestone. 3. *Sandstone,* often carbonaceous, with clays, full of leaves of terrestrial plants; *beds of coal* and *ironstone.* 4. *Limestone,* ferruginous and concretionary sands.

LOWER OOLITE of Brora in Scotland.	1. *Shelly limestones*—alternations of sandstones, shales, and ironstone, with plants. 2. *Ferruginous limestone,* with carbonized wood, leaves, shells, and cyprides. 3. *Sandstone and shale,* with *two beds of coal.*

LIAS.

LIAS of Dorsetshire, Somersetshire, Northamptonshire, and Yorkshire.	1. *Upper Lias shale,* replete with remains of reptiles, especially of Ichthyosauri and Plesiosauri; Crinoidea in profusion: Crustacea: belemnites, ammonites, &c.; nodular concretions and beds of limestone. 2. *Lias marlstone*—calcareous, sandy, and ferruginous strata, very rich in terebratulæ and other fossils; wood, ferns, and cycadeous plants, &c. 3. *Lower Lias clay and shale*—abounding in shells—*gryphea incurva,* &c.—interlaminations of sands and nodules of limestone. 4. *Lias rock;* a series of laminated limestones, with partings of clay.

This list, extensive as it appears, exhibits only the principal deposits observable in the extensive series comprised in the Oolitic system. The difference observable between the lower beds of the Oolites of the midland counties, and those of Yorkshire and Scotland, in the presence of accumulations of vegetable matter in the state of coal, with the remains of terrestrial plants; together with the relics of insects, land-plants, and *Mammalia,* in the Stonesfield slate, attest the existence of land, and the action of rivers and currents. Our previous observations on the nature of oceanic deposits (*ante*, p. 57), will have prepared the intelligent reader for such intercalations of terrestrial detritus and organic remains in the beds of the ancient seas.

From the above table it is seen that the *Inferior* or *lower Oolite* rests on the argillaceous beds termed *Lias clays:*

and that upon it is superimposed the *Oxford clay;* next follows the *Middle Oolite;* which is surmounted by another thick argillaceous deposit, the *Kimmeridge clay;* and upon this is the *Portland* or *Upper Oolite.*

7. OOLITE, OR ROE-STONE.—The limestones of this formation have very generally a peculiar structure, being composed of an aggregation of small rounded grains or spherules, presenting some resemblance to clusters of small eggs, or the roes of fishes; whence the name *oolite,* or *egg,* or *roe-stone,* which is now applied, not only to limestones possessing this character, but also to the entire series of deposits which intervenes between the Chalk and Wealden above, and the Lias below. On the Continent the group is generally termed "*Terrains Jurassiques,*" from the Jura mountains that divide France from Switzerland being largely composed of these deposits.

The oolitic structure is not however confined to this division of the secondary rocks; for it occurs in tertiary, and also in some of the most ancient sedimentary strata. It consists of an aggregation of grains or globules of calcareous matter, composed of concentric laminæ which commonly have an atom of sand, or a minute shell or coral, as a nucleus. These globules owe their formation to the deposition of successive spheroidal concretions around the included body while subjected to the action of water in which a rotatory motion is induced; and the spheroids continue to increase, till they become too heavy for further transport, and then subside, and are consolidated by subsequent infiltration. When the individual spheres are of a large size, the aggregated mass is called *pisolite,* or peastone. The springs near Carlsbad deposit a beautiful conglomerate of this kind, some masses of which are sufficiently compact to admit of being manufactured into boxes, and other ornaments. Polished slices exhibit every variety of sections of the concentric layers of which the concretions are composed ; and as the colour varies from a pure white to a delicate brown, the surface is elegantly marked with zones of various tints.

8. Geographical distribution of the oolite.—The strata above enumerated form a striking feature in the physical geography of England, from the southern shore of Dorsetshire to the Yorkshire coast. They constitute a table-land of considerable elevation, the greatest heights amounting to 1500 feet, which extends in a tortuous line from the Dorsetshire coast, through Somersetshire, Wiltshire, Gloucestershire, Oxfordshire, Northamptonshire, and Lincolnshire, to the eastern shores of Yorkshire. This tract generally presents a bold escarpment to the west, and slopes gradually to the east, dividing the eastern and western drainage of that part of England.*

Certain subdivisions of the Oolite predominate in particular localities ; thus, the Oxford clay prevails in the midland counties, — the grey rubbly limestone, called Cornbrash, at Malmsbury, Chippenham, &c.—the Forest marble in Oxfordshire and Somersetshire,—the Great Oolite, at Bath,—the Stonesfield slate, near Woodstock,—and the Inferior Oolite, in the Cotteswold hills.

On the Continent the Oolite appears in Normandy, and its characteristic fossils prevail in the quarries around Caen ; diverging into several branches or ranges of hills, it traverses France, forms the chief feature of the Jura mountains, and constitutes part of the Alps ; and in the latter, strata belonging to this system appear greatly altered in their mineralogical composition from the effect of metamorphic action. The Oolite of the continent contains the lithographic stones and slates of Pappenheim, Solenhofen, Manheim, &c. ; some beds of which are celebrated for the beauty and variety of their fossil remains.

* See Geology of Yorkshire, by Professor Phillips.

The Lias forms a district that lies parallel with the escarpment of the oolite, from beneath the base of which it emerges; it traverses the country from the well-known cliffs at Lyme Regis in Dorsetshire, to near Redcar, on the Yorkshire coast.

9. RAILWAY SECTIONS.—In a previous lecture (vol. i. p. 363) we described the sections presented by the south-eastern railway, as affording a coup-d'œil of the geological structure of that part of England: in like manner the lines that traverse our Island in other directions enable the instructed observer to obtain a general idea of the geographical distribution and position of the principal groups of the rocks and strata.

More than a quarter of a century since, the information to be derived from such a survey was admirably pointed out by Mr. Conybeare.* "If," observes that eminent geologist, "we suppose an intelligent traveller taking his departure from the metropolis, to make from that point several successive journies to various parts of this Island, for instance, to North or South Wales, or to Cumberland, or Northumberland, he cannot fail to notice (if he pays any attention to the physical geography of the country through which he passes) that before he arrives at the districts in which Coal is found, he will first pass a tract of clay and sand; then another of Chalk; that he will next observe numerous quarries of the calcareous freestone used in architecture; that he will afterwards pass a broad zone of red marls and sands, and beyond this will find himself in the midst of coal mines and iron furnaces. This order he will find to be invariably the same, whichever of the routes above indicated he pursues; and if he proceeds further, he will perceive near the limits of the coal fields, hills of compact limestone, affording grey and dark marbles,

* Geology of England and Wales, p. ii.

and abounding in mines of lead and zinc; and at a yet greater distance, mountainous tracts in which roofing slate abounds and mineral veins yet more valuable; and lastly, he will often find, surrounded by these slaty tracts, central groups of granitic rocks."

The Great Western Railway, from London to Bath, and the Birmingham line from Euston Square to Derby, respectively traverse the strata comprised in the oolitic system; for our present purpose the former will afford the most instructive illustration. From the Paddington station, which is situated on London Clay (p. 229,) the line passes along tertiary strata, by Ealing, Hanwell, and Slough, and enters the chalk near Maidenhead; beyond Wallingford it traverses the clays and limestones of the Oolite, and the cuttings in many places exhibit good sections of these deposits. Near Bath it emerges on the Lias, and crossing a narrow belt of Triassic strata, passes on to the Carboniferous beds of the Bristol coal-measures. In this route there are several localities of considerable interest, as Faringdon, Swindon, Chippenham, Calne, &c. to which we shall allude hereafter.*

10. SUBDIVISION OF THE OOLITE:—PORTLAND OOLITE.†—Beds of limestone, having the structure above described,

* See Medals of Creation, vol. ii. Geological Excursions to Clifton, p. 922; and, for the section exposed by the Birmingham and Derby line, Excursions to Matlock, p. 933.

Mr. Hugh Miller contrasts the appearance of these railway sections, in consequence of the low angle of inclination in which the secondary strata in England generally lie, with those of Scotland, as laid bare in the line from Glasgow to Edinburgh. There every few hundred yards in the line brings the traveller to a trap rock, against which the strata are tilted at every possible angle of elevation.

† For details of the geological phenomena exhibited by the beds below the Chalk, and above the New Red sandstone, in the South-east of England, Dr. Fitton's elaborate memoir, in the Geol. Trans. (*new series*) vol. iv. should be consulted.

form the principal lithological features of the calcareous portion of the Oolite, and the uppermost deposits consist of a series of such strata abounding in marine shells. From the great employment of certain beds of this stone for architectural purposes, and the extensive quarries that have for centuries been worked in the Isle of Portland, this upper group is called the Portland oolite. In the south of England, as we have already had occasion to mention,* the Portland beds are covered by the Wealden strata, and in some places by layers of vegetable mould, and petrified upright trunks of pine-trees. In the inland counties, as Wiltshire, Berkshire, &c., they are overlaid by the lowest member of the cretaceous formation, the Greensand, no intercalations of fresh-water deposits being apparent; but the oolite limestone, full of terebratulæ, trigoniæ, ammonites and corals, is immediately covered by sand and sandstone, containing other species of the same genera of marine shells. The lower part of this group is composed of a bed of sand (*Portland sand*) from 50 to 80 feet thick, which gradually passes into the underlying clay. The fossils of the Portland beds are very numerous ; large ammonites, pleurotomariæ, trigoniæ, pectens, oysters, pernæ, terebratulæ, turritellæ, &c. and bones of saurians, and drifted coniferous wood, are among the prevailing organic remains.†

11. THE KIMMERIDGE CLAY.—This argillaceous deposit consists of dark bluish and grey clay, which in some parts passes into highly bituminous shale ; the name is derived from Kimmeridge in Dorsetshire, where some of the layers are sufficiently combustible to be used as fuel.‡

* See Geological Excursion round the Isles of Wight and Portland, p. 393.

† As a British locality exhibiting the Portland strata and their characteristic fossils, Swindon in Wiltshire is the most interesting with which I am acquainted. See Geological Excursions in my Medals of Creation, vol. ii. p. 927.

‡ Kimmeridge Coal. See Excursions round the Isle of Wight, p. 367.

This deposit is in some places 300 feet in thickness, but thins out to a very inconsiderable layer in some localities; and in the northern counties of England is altogether wanting.

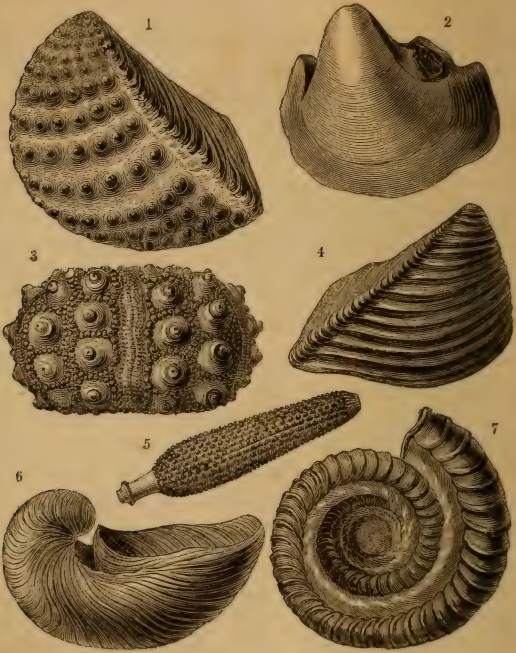
Around Hartwell in the vale of Aylesbury, in Buckinghamshire, this clay is largely developed, and abounds in organic remains of great beauty and interest. I know of no locality which has yielded such splendid specimens of Ammonites, Rostellariæ, Pleurotomariæ, Pernæ, &c.; the nacreous or pearly coat of the shells of the ammonites is often as perfect and splendid with iridescent colours as in a polished recent nautilus shell. Many of the shells, of which casts only occur in the Portland rock above, are found preserved entire in the clay. A flat oyster of a deltoid form (*Ostrea deltoidea*) is very abundant, and is generally considered as peculiar to this clay, but it occurs also in the Oxford clay, which is lower in the series.

Bones of Ichthyosauri, Plesiosauri, and Cetiosauri, are occasionally found: and scales, teeth, and other remains of fishes, among which are mandibles of the Chimæroids.*

12. The Oxford Oolite.—The Kimmeridge clay rests on beds of coralline limestones, provincially termed *Coral-rag*, many of which are literally petrified coral-reefs, consisting of coarse limestone, composed of madrepores, astreæ, caryophylliæ, and other stony corals, having the interstices filled up with shells, echinoderms, sand, and pebbles; the whole is more or less consolidated by calcareous, and in some instances by siliceous, infiltrations. So obvious is the origin of these rocks, that the most incurious observer who travels through the districts where these deposits prevail, cannot fail to remark the blocks of coral which every-

* The extensive Museum of Dr. Lee of Hartwell contains a fine collection of fossils from the neighbourhood, to which strangers are allowed free access by the learned and liberal proprietor.

where meet his view in the quarries and on the road-side. In many parts of Wiltshire, Berkshire, and Gloucestershire,



LIGN. 111.—SHELLS AND ECHINITES FROM THE OOLITE AND LIAS.

Fig. 1. Trigonia clavellata; from the Oxford clay.
2. —————————; a limestone cast, from Portland.
3. Cidaris Blumenbachii; Oolite, Calne.
4. Trigonia costata; Oolite, Highworth.
5. Spine of fig. 3.
6. Gryphæa incurva; Lias.
7. Ammonites Walcotii; Lias.

the Coral-rag is extremely rich in organic remains; corals, shells, and echinites, occurring in almost every mass of stone. From the pits near Faringdon* I have collected hundreds of specimens in the course of a few hours ; and the quarries near Calne, in Wiltshire, abound in echinites of that beautiful species popularly called "*Fairies' night-caps*" (*Cidaris*, *Lign.* 111, *fig.* 3), which are often surrounded by their spines, in as perfect a state as if they had just sunk down into soft sand or mud ; detached spines of these animals are found (*Lign.* 111, *fig.* 5,) in immense numbers.†

Many species of the bivalves called *Trigoniæ*,‡ of which only one species, an inhabitant of the seas of Australia and New Zealand, is known living, occur in these beds in great perfection and abundance ; two species are here figured (*Lign.* 111) ; limestone casts of these shells are very frequent in the Portland stone, and are generally accompanied with turritellæ, terebræ, and other spiral univalves.

13. Oxford Clay.—The Coral-rag rests upon a bed of clay, in many places 300 feet thick, which is characterized by the abundance and variety of its organic remains. Some localities in Wiltshire are celebrated for the state of perfection in which many species of extinct cephalopoda occur. At Christian Malford, near Chippenham, the cuttings for the Great Western Railway, brought to light specimens of the soft parts of the animals allied to the Sepiadæ, or Cuttle-fish, whose shells are so abundant in the argillaceous

* Most of the heights around Faringdon are capped with Greensand, overlying Coral-rag. Stanford pit, three miles south-east of Faringdon, contains:—1. Uppermost, Coral-rag, 3½ feet; 2. Limestone, with immense numbers of shells, 4½ feet; 3. Sand, 3 feet; 4. Clay. These beds abound in trigoniæ, gervilliæ, terebratulæ, ostreæ, belemnites, and ammonites: in a slab of coarse sandy limestone, four feet square, I counted above fifty gervilliæ, and many trigoniæ. Between Watchfield and Shrivenham the Coral-rag is seen in openings on the road-side. See Medals of Creation, vol. ii. p. 923.

† See Medals of Creation, vol. i. p. 343, for a particular account of these fossils.

‡ Ibid. p. 407.

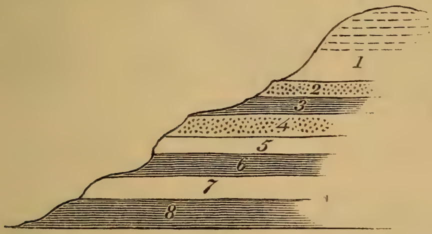
deposits of the Oolite. The *Belemnoteuthis* (of the late Mr. Channing Pearce),* an extinct cephalopodous mollusk allied to the Belemnite, but in all probability generically distinct, has been found with its arms entire, and the acetabula or suckers, and spines attached.† In the works now in progress for a branch railway through Trowbridge, the Oxford clay underlying beds of Coral-rag, has been largely exposed, and has yielded innumerable specimens of the usual fossils, and some species of ammonites and other shells not previously observed.‡ The members of the upper

* See London Palæontological Journal, No. 2, Pl. XV. XVI., for beautiful figures of several remarkable specimens of these extinct Cephalopoda.

† In the Hunterian Museum are some splendid examples, presented by the Marquess of Northampton and P. Pratt, Esq., which Prof. Owen regards as the soft bodies of the Belemno-sepia; but the correctness of this appropriation has lately been disputed.

‡ My son, Mr. Reginald Neville Mantell, who is engaged on this work under Mr. Brunel, has made a large collection of the fossils brought to light by the cuttings and excavations in this locality. It comprises very large and fine specimens of *Ammonites Königi, A. Calloviensis, A. sublævis, A. athleta*, &c.; beautiful examples of a boat-like ammonite with a sharp keel (*A. Chamusseti* of M. D'Orbigny, probably *A. funiferus* of Prof. Phillips); a large depressed ammonite, with a flat back, and a single row of nodular tubercles on the wreaths, which appears to be an undescribed species: several kinds of Nautilus; Belemnites with the phragmocone and traces of the soft parts; the cartilaginous base of the *Belemnoteuthis*; innumerable small shells of the genera *Rostellaria, Terebra, Turritella, Trocthus*, &c.; Ostreæ deltoideæ; Grypheæ, Terebratulæ, &c.; masses of coniferous wood and lignite; bones of Ichthyosauri, Plesiosauri, Teleosauri, &c.: and a few relics of fishes. The fossils enumerated are but a small portion of the exuviæ of the oolitic ocean, which have been dug up in the comparatively small area traversed by the railway; and the profusion of shells, some of which are inhabitants of deep waters, and others of shallow shores, here intermingled with drift-wood, attests the effects of sub-marine currents by which the remains of mollusks of such different habitats were accumulated and spread over this area of the sea-bottom, with the spoils of the land transported from a distance by streams and rivers.

part of the oolitic system occur through this part of Wiltshire in their natural order of succession ; as is shown in the following section (*Lign.* 112), in which the subdivisions of the Chalk and Oolite, from the Upper or flinty Chalk down to the Oxford clay, are seen in a nearly horizontal and conformable position.



LIGN. 112.—SECTION FROM THE WILTSHIRE CHALK-DOWNS TO THE OXFORD CLAY.

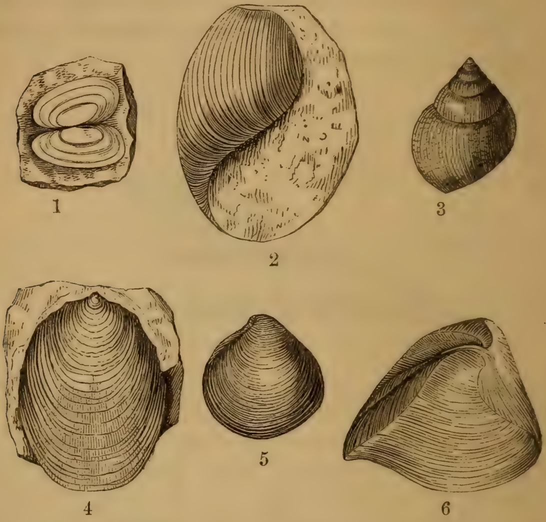
1. Upper and Lower White Chalk. 2. Firestone. 3. Galt. 4. Greensand. 5. Portland Oolite. 6. Kimmeridge Clay. 7. Coral-rag. 8. Oxford Clay.

14. KELLOWAY ROCK, AND CORNBRASH.—A bed of gritty arenaceous limestone, a few feet in thickness, is intercalated in the Oxford clay, and is remarkable for the abundance of shells, and other organic remains which it contains. It is called the Kelloway rock : hence a common species of ammonite in this deposit is named *A. Calloviensis.*

Cornbrash.—Under the Oxford clay a stratum of rubbly hard limestone, from ten to twelve feet thick, is generally met with, which, like the Kelloway rock, swarms with many species and genera of marine shells, associated with other fossils. This bed is provincially termed Cornbrash. I subjoin figures of a few peculiar shells from the neighbourhood of Scarborough in Yorkshire, which were first described by Mr. Bean.*

* See "A Catalogue of the Fossils found in the Cornbrash Limestone of Scarborough, Yorkshire," by William Bean, Esq.—*Mag. Nat. Hist.* vol. iii. p. 57.

In Wiltshire the Cornbrash is succeeded by the strata termed Forest Marble, Bradford Clay, Great Oolite, and, lastly, by the lower beds of the system.*



Lign. 113.—Shells from the Yorkshire Cornbrash.

Fig. 1. Sanguinolaria parvula.
2. Bulla undulata.
3. Littorina punctura.
4. Anomia semistriata.
5. Cardium globosum.
6. Isocardia triangularis.

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* The admirable memoir by Mr. Lonsdale, on the Geology of the country around Bath, should be consulted by those desirous of more ample information on the oolite of that part of England; Geol. Trans. vol. iii. p. 242;—and Professor Phillips's Geology of Yorkshire, for a full account of the oolitic system of the eastern moorlands of that county. My son informs me that wherever the railway excavations have traversed the district described by Mr. Lonsdale, he has found that gentleman's sections and descriptions of the strata accurate even in the minutest details.

The *Bradford Clay.*—In the neighbourhood of Bradford, in Wiltshire, a subordinate bed of the forest marble or blue limestone of the Great Oolite, is remarkable for the abundance of the remains of a particular species of crinoidean, called the *Pear-encrinite* of Bradford (*Medals*, p. 318), which in some places occur under circumstances apparently indicating that the animals still occupy the spots where they grew. The clay is spread over the surface of a stratum of limestone, and many of the Stone-lilies are upright, with their root-like base attached to the calcareous rock. "In this case," observes Mr. Lyell, "it appears that the upper surface of the Great Oolite had supported for a time a thick submarine forest of these beautiful zoophytes, until the clear and still water was invaded by a current charged with mud, which threw down most of the stone-lilies, and broke their stems short off near the point of attachment. The stumps still remain in their original positions; but the numerous articulations once composing the stems, arms, and body of the zoophytes, were scattered at random through the argillaceous deposit, in which some of them now lie prostrate."*

15. THE COTTESWOLD HILLS.—As the elevated tract of country called the Cotteswold hills, which extends for thirty miles through the county of Gloucester, in a N.E. and S. W. direction, having an average breadth of ten or twelve miles, exhibits the principal characters of the English Oolites, the following brief description will convey a general idea of the physical geography and lithological structure of a district composed of these deposits.†

"The surface of this district has a general inclination to the S.E. its eastern borders having an elevation of about 400 to 500 feet above

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* Elements of Geology, 2d Edit. vol. ii. p. 45.

† I am favoured with this account by Professor Woodward, of the Agricultural College of Cirencester.

the sea; whilst the western ranges from 600 to 800 feet, and the culminating point, Cleeve Cloud, is 1,134 feet high.

"The branch of the Great Western Railway from Swindon to Gloucester passes through the centre of the district, and affords a key to its geological structure.

"These hills are entirely composed of two series of oolitic limestones, separated by a bed of clay known to geologists as the 'Fuller's earth.' The strata are inclined to the S.E., at the rate of about 1 in 130, or less than half a degree; yet this inclination is greater than that of the general surface, and sufficient to carry the hill strata beneath the newer formations on the S.E.; whilst on the N.W. boundary they terminate in steep escarpments, that are broken and indented by numerous deep and picturesque valleys.

"In order to obtain a general idea of the nature and succession of the strata of the whole district, we may conveniently pursue the well-known Roman road termed the '*Irmin Way*,' which coming from Newbury through the Wanborough downs, runs almost in a straight line to Cricklade, Cirencester, Birdlip, and Gloucester, and traverses in succession the whole of the oolitic strata, in the following order:—

> "1. Portland stone. 2. Kimmeridge clay. 3. Coral rag. 4. Oxford clay and Kelloway rock. 5. Great Oolite: subdivided into Cornbrash, Forest marble, Bradford clay, Bath freestone, Stonesfield slate. 6. Fuller's earth. 7. Inferior Oolite. 8. Lias.

"1. The *Portland stone* is extensively quarried near Swindon Old Town.

"2. The *Kimmeridge clay* forms the valley in which the Swindon station and the New Town are situated.

"3. The *Coral rag* rises up from beneath the clay, and constitutes the hills about Stratton, Saint Margaret's, Pen Hill, and Blunsdon.

"4. The *Oxford clay* occupies the whole of Braydon Forest, and the wide valley around Cricklade, but is covered in many places by thick beds of oolitic gravel.

"5. At Driffield cross-ways the *Cornbrash* is seen in the small quarries from which the road-stone is procured; and in descending the hill towards Cirencester we pass to the *Forest marble*, a thin-bedded stone, well shown in the quarries at Preston, from which much of the roofing-stone and planking, so extensively used in the neighbourhood, is obtained. A bed of clay is usually found separating the Forest marble from the Bath freestone, and is therefore the equivalent of the *Bradford clay*. Beyond Stratton the road lies over the Bath freestone (or '*Hampton stone*') as far as Highgate, where several deep valleys expose the *Stonesfield slate, Fuller's earth*, and *Inferior Oolite.*

"The quarries near Birdlip also exhibit the Inferior Oolite, and the remainder of the road to Gloucester rests upon the *Lias*.

"If an Artesian well were sunk at Swindon New Town, it would probably pass through the above-mentioned strata, from the Kimmeridge clay to the Lias, in the same order in which they are passed over by the Irmin Way, reaching the surface of the Lias at a depth of about 1000 feet."

16. THE STONESFIELD SLATE.—I have already stated that the zoological characters of the Oolite and Lias are decidedly marine; the interspersions of fresh-water and terrestrial sediments having been produced by the accumulation of materials brought down by streams and rivers into the sea, and transported by currents to a distant part of the oceanic basin. Unlike the organic remains of the Wealden, the terrestrial and fresh-water productions are mingled with marine plants, shells, and fishes; thus, while the Chalk consists of the bed of a deep sea with scarcely any intermixture either of land or fresh-water debris, and the Wealden of a delta in which but very few marine exuviæ are imbedded; the intercalations in the oolitic series present a combination of these characters, of which the Stonesfield strata afford a highly interesting example.

Stonesfield, a small village near Woodstock, about twelve miles north-west of Oxford, has long been celebrated for the fossils imbedded in its slaty limestone; bones and teeth of large reptiles, and of fishes, and other remains from this locality, were described and figured by Lhwyd, a century ago.* The "Geology of England and Wales," by Messrs. Conybeare and Phillips, which every one must regret has not been continued and completed by the highly-gifted author who survives, contains a description of the Stonesfield strata, and a brief enumeration of the fossils which they inclose.

On my discovery of the fluviatile origin of the strata of Tilgate Forest, I was led to institute a comparison between

* Lithophylacii Britannici Ichnographia.

the fossils of the Wealden and those of Stonesfield, and the result appeared in my first work on the Geology of Sussex, in 1822.* A valuable memoir by Dr. Buckland, on the fossil reptile of Stonesfield, the Megalosaurus,† again drew attention to these interesting deposits, and it was expected that this distinguished philosopher would follow up the investigation, and give a full description of the organic remains.

The Stonesfield strata have been ascertained, by Mr. Lonsdale, to belong to the lower division of the Great Oolite; the following account, by Dr. Fitton,‡ explains the circumstances under which they occur. "In crossing the country from Oxford to Stonesfield, the Oxford clay, with its characteristic fossils, is first observed; this is succeeded by the *Cornbrash*, the uppermost stratum of the great oolite group, which is seen beneath the clay in several quarries on the road-side between Woodstock and Blenheim. The village of Stonesfield is situated on the brow of a valley, both sides of which are deeply excavated by the shafts and galleries that have been constructed for the extraction of the slate. The beds that supply the stone are at a depth of about fifty feet below the summit, and are worked by shafts. The upper twenty-five feet consist of clays alternating with calcareous stone; the lower of fine-grained oolitic limestone, with numerous casts of shells." From the bottom of the shaft, a drift or horizontal excavation is made around, extending as far as safety will permit; the beds above being supported by piles of the less valuable materials. The strata thus worked do not exceed six feet in thickness; they consist of rubbly stone, with sand imbedding large concretional masses of fine sandy grit, which,

* Illustrations of the Geology of Sussex, p. 37.
† Geological Transactions, vol. i. New Series.
‡ Zoological Journal, vol. iii. p. 416.

by exposure to the frost, admits of separation into thin flakes.

The resemblance of this calciferous grit to that of Tilgate Forest is most striking; and when breaking it, and perceiving here and there teeth and scales of fishes and bones of reptiles like those of the Wealden, I could have fancied myself sporting on my own geological manor of Tilgate Forest, but for the trigoniæ and other marine shells, and the oolitic structure which every where prevailed. The grit, like that of Sussex, passes into a conglomerate, formed of smooth rounded pebbles, cemented together by calcareous stone; beds of sands, clay, and friable slaty sandstone, intervene between the layers of the oolitic rock. Grits, and shales similar to those of Stonesfield, occur also at Wittering and Collyweston, associated with beds of oolite limestone, and contain ferns and other terrestrial plants, and marine shells.

17. Organic Remains of the Stonesfield Slate.—The fossils of Stonesfield, although of so highly interesting a character, have hitherto been very imperfectly investigated. The vegetable remains consist of several species of *Fucoid* plants; of palms, arborescent ferns, and plants allied to the Zamia and Cycas; and a genus of *Liliaceæ*, named *Bucklandia;* seed-vessels, leaves, and stems, of several genera of coniferæ; and traces of reeds and grasses. I am not aware that the shells differ from those of the other oolitic strata; one small bivalve (*Trigonia impressa*) is extremely abundant. The bones and teeth of the gigantic terrestrial reptile related to the Monitor, the *Megalosaurus*, which I have mentioned as occurring in the Wealden (*ante*, p. 421); bones of *Pterodactyles*, or flying lizards; bones and plates of Turtles; and other osseous remains, apparently of saurians, present a striking general correspondence with the fossils of the Wealden. The *elytra*, or wing-cases of beetles, and other relics of insects, are of frequent occurrence. The teeth,

scales, fin-bones, and rays of fishes, belong for the most part to the same genera and species as those contained in other beds of the oolite; round hemispherical teeth of species of *Lepidotus* and *Hybodus* are every where met with.*

18. FOSSIL MAMMALIA OF STONESFIELD.†—In addition to the animal and vegetable remains above enumerated, the laminated oolitic limestones of Stonesfield have yielded some of the most precious relics of the past ages of our

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LIGN. 114.—THE RIGHT SIDE OF THE LOWER JAW OF A MARSUPIAL MAMMALIAN; FROM STONESFIELD.

Fig. 1. Natural size. Fig. 2. Enlarged view of a single tooth.

(*Phascolotherium Bucklandi.*‡)

globe—the only known vestiges of mammalian animals in the secondary formations; in other words, in deposits of an

* See Dr. Buckland's Bridgwater Essay for figures of several fossils from Stonesfield.

† Medals of Creation, vol. ii. p. 852.

‡ The original is in the British Museum; it is in an admirable state of preservation, and the piece of slate in which it is imbedded, has numerous casts of the *Trigonia impressa,* which occur in such profusion in the Stonesfield slate.

age antecedent to the most ancient eocene epoch :—a fact of the highest interest to the geologist, since it carries back the existence of the higher vertebrated animals to a period of unfathomable antiquity.

The mammalian remains hitherto discovered consist of six specimens of portions of the lower jaw, with teeth ; these all belong to very small animals, and are referable to two genera. One is allied to the *Wombat*, a marsupial animal of New South Wales (the *Phascolomys*) ; proving that the remarkable character of the mammalian fauna of Australia also prevailed in a very remote period, and that it is not, as some have inferred, a new order of things. The other remains indicate a small insectivorous mammal, (*Amphitherium*) having thirty-two teeth in the lower jaw ; its marsupial affinities are doubtful.*

19. Comparison of the Stonesfield and Wealden Fossils.—The reader cannot fail to remark the general correspondence that exists between the organic remains imbedded in these fluvio-marine deposits of the Oolite and those of the Wealden : the following tabular view will render this analogy more obvious :—

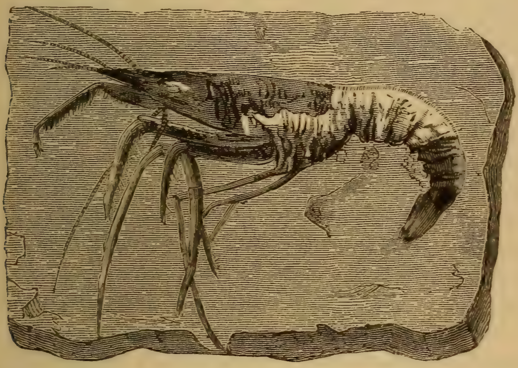
Strata of Tilgate Forest.	*Stonesfield Slate.*
Drifted coniferous wood, lignite, &c.	Drifted coniferous wood.
Equiseta.	Fucoid plants.
Herbaceous ferns ; Sphenopteris, Lonchopteris, &c.	Herbaceous ferns : Sphenopteris, Tæniopteris, &c.
Cycadeæ and Zamiæ.	Cycadeæ and Zamiæ.
Endogeniteserosa.	Liliaceæ.
Clathraria Lyellii.	Bucklandiæ.
Carpolithes ; and undetermined seed-vessels.	Carpolithes, and undetermined seed-vessels.

* See Prof. Owen's British Fossil Mammals, for exquisite figures, and an elaborate philosophical notice of the mammalian remains discovered in the Stonesfield slate.

Freshwater shells: Paludinæ, Cyclades, Uniones, &c.	Marine shells—Trigoniæ, &c.
Freshwater Crustaceans: Cyprides.	Marine Crustaceans:—Astacidæ, &c.
Insects: numerous genera.	Insects: several genera.
Fishes of the genera Hybodus, Lepidotus, &c.	Fishes of the genera Hybodus, Lepidotus, Psammodus, &c.
Marine and Freshwater Chelonians.	Marine Chelonians.
Reptiles: *marine*—Plesiosaurus and Cetiosaurus.	Plesiosaurus and Cetiosaurus.
——, *terrestrial*—Megalosaurus, Hylæosaurus, Iguanodon, &c.	Megalosaurus.
Crocodilian Reptiles: Streptospondylus, Pœcilopleuron, &c.	Pœcilopleuron.
Pterodactyles.	Pterodactyles.
Birds—? ?	Mammalia: species of two genera.

From this table we perceive at a glance, that the fauna and flora of the dry land during the deposition of the Stonesfield oolite and the Wealden strata were essentially the same; while the difference in the mollusca points out the respective conditions under which the deposits took place. The fresh-water shells of the Wealden indicate the bed either of a delta, or of an inland lake: the marine shells of the Stonesfield strata, the basin of a deep ocean. Hitherto no vestiges of warm-blooded quadrupeds have been found in the Wealden, nor in any other of the secondary strata. The Stonesfield beds alone have afforded evidence of the early existence of the higher orders of vertebrated animals, allied to genera now restricted to New South Wales and Van Diemen's Land. It is a most interesting fact, as Professor Phillips was the first to remark, that the organic remains with which these relics are associated, also correspond with the existing forms of the Australian continent and neighbouring seas; for it is in those distant latitudes that the waters are inhabited by Cestracions, Trigoniæ, and Terebratulæ: and that the dry land is clothed with Araucariæ, and Cycadeous plants.

20. Lithographic Oolite of Germany.—The quarries in Germany, which yield the fine-grained fissile calcareous stone so much employed in lithography, afford also a rich assemblage of organic remains, of the highest interest. The lithographic deposits are found in that prolongation of the chain of the Jura which, after the fall of the Rhine at Schaffhausen, passes into Germany along the borders of the Maine, and near to Cobourg. The quarries are situated on the sides of the valley of the Altmuhl, a tributary of the



Lign. 115.—Fossil prawn, from Pappenheim.
(*Palæmon spinipes.*)

Danube, that extends by Pappenheim and Aichsted. This valley presents a precipitous escarpment, which is composed of, 1. The uppermost part; calcareous schist, containing in abundance, fishes, crustaceans, asteriæ and reptiles, with a few small ammonites and bivalve shells;—2. a magnesian limestone;—3. limestone of a greyish white, abounding in ammonites; and 4. brown, or grey sandstone, of a fine grain, constituting the base of the hills of the district. The most celebrated quarry of the calcareous schists, is that of Solenhofen, near Pappenheim.* The cream-coloured limestone of this quarry has long been known to contain organic remains of great beauty and interest. Crustaceans allied to the Lobster, Shrimp, Cray-fish, &c. are often met with, and many specimens are figured by authors. Knorr's splendid work, "*Monumens des Catastrophes que le Globe terrestre a essuié*," contains numerous coloured representations of these fossils. The Prawn here figured (*Lign* 115) shows the extraordinary state of preservation of these remains. A Saurian, about three feet in length, allied to the crocodile, has been found at Solenhofen; and Count Munster has collected many species of Pterodactyles, saurians, and tortoises; upwards of sixty species of fish; forty-six of crustaceans, and twenty-six of insects. There are but few shells and plants, and these are all marine.

Sir H. De la Beche remarks, that the fact of the greatest number of fossil insects yet noticed in the oolite, having been found where the remains of the Pterodactyles principally occur, seems to establish a connexion between these creatures, not merely accidental; and that it is probable the whole of the deposits of this local group of the Jura limestone, may have been effected on a coast where the water was not deep, and on the shores of which the flying reptiles chased their insect prey.†

21. CARBONIFEROUS STRATA OF THE OOLITE.—In the tertiary system of Provence, we noticed the occurrence of beds of coal with limestone containing fresh-water shells and crustaceans (*ante*, p. 260); and in the lacustrine deposits of the Rhine, accumulations of brown coal and lignite (p. 278). In the Wealden of the South-east of

* Oss. Foss. tom. v.

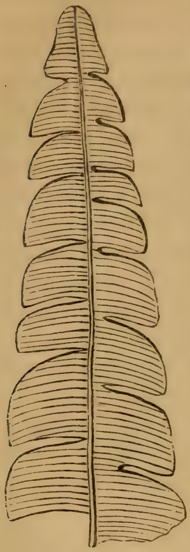
† A beautiful fossil Dragon-fly from Solenhofen (in the rich collection of the Marquess of Northampton) is figured in Medals of Creation, vol. ii. p. 574.

England, lignite and thin seams of coal are associated with shale and laminated sandstones, so much resembling the ancient carboniferous beds, as to have led to an expensive and abortive search for coal; while in the north of Germany, the Wealden contains a rich coal-field of considerable extent. The fluvio-marine strata of Stonesfield, though teeming with vestiges of land plants, enclose no considerable masses of vegetable matter; but in the extension of these lower beds of the Oolite northward, indications of lignite and carbonized plants become more abundant; and along some parts of the Yorkshire coast seams of coal and numerous fossil vegetables occur; proving that the currents of fresh-water which flowed into that part of the oceanic basin of the Oolite were occasionally loaded with trees and terrestrial plants, transported from the lands inhabited by the Megalosauri, Pterodactyles, and small Mammalians, whose remains are found at Stonesfield. On the western shores of Scotland, strata of a similar character are exposed.

Professor Phillips has fully described the carboniferous beds of the Yorkshire oolite,* and Sir R. Murchison those of Sutherlandshire; the tabular arrangement, p. 492, shows the succession of the deposits in these two localities.

In the district north of the Humber, the lower Oolite assumes a new character: instead of finding beneath the Cornbrash, the Forest marble and Great Oolite, we meet with beds of sandstone, and shales abounding in coaly matter, interpolated above the sand which covers the Lias. Proceeding northwards, these strata rapidly increase in thickness, and the carbonaceous layers gradually become concentrated into a stratum of coal, which, though never exceeding sixteen inches in depth, is, from local circum-

* Encyclopædia Metropolitana, art. *Geology;* and the Geology of Yorkshire, by the same eminent philosopher.



LIGN. 116.—PART OF A LEAF OF PTEROPHYLLUM COMPTUM: from near Scarborough.

stances, of considerable value. These strata assume the appearance of a true coal-field, with subordinate beds of coarse, shelly limestone. The fossil plants which accompany the coal-seams and sandstones, occur also in the calcareous slates and limestones, both on the Yorkshire coast and at Bransby. No marine exuviæ have yet been found in the coal grits or shales, with the exception of some bivalves. Along the coast under Gristhorp cliffs, a seam of shale, but a few inches in thickness, may be traced for miles; and, from its abounding in leaves of ferns, and equisetaceous and cycadeous plants, it is chiselled out by collectors to obtain specimens; for the beauty and variety of these fossils render them objects of great interest. Detached leaves (*Lign.* 116) in a carbonized state are very abundant, and their venation is generally well preserved. Professor Phillips has figured several kinds in his Geology of Yorkshire: and numerous species are described in the British Flora.* The fruits of Zamiæ also occur, and many splendid examples are preserved in the British Museum, and other collections. This specimen (*Lign.* 117) shows the usual appearance of these fossil cones; it is imbedded in dark ironstone shale, and the leaves and their imprints are covered with a white hydrate of alumine. The fossils described by some authors as flowers, are conjectured to be cones of this kind, broken transversely, in

* See also Medals of Creation, vol. i. p. 155.

which state the scales may be mistaken for petals, and the fractured axis for the stamen and pistillum.

LIGN. 117.—FRUIT OF A CYCADEOUS PLANT, FROM SCARBOROUGH.

The seeds are concealed by the leaflets.

(*Zamites lanceolata.*)

Here, observes Professor Phillips, we have truly a coal-field of the oolitic era, produced by the intercalation of vast quantities of sedimentary detritus loaded with vegetable matter, brought down by floods from the land, between the more exclusively marine strata of the ordinary oolitic type.

22. COLLYWESTON SLATES.—Near Stamford, in Lincolnshire, the lowermost visible strata are Lias clays, upon

which are spread the inferior oolite strata, full of characteristic fossils; and above are beds of laminated calcareous stone, locally termed the Collyweston slates, from being quarried in that neighbourhood. These deposits, therefore, occupy the same geological position as the Stonesfield slate of Oxfordshire and of the Cotteswold hills, and contain similar marine shells. The upper series consists of marly limestone and shale, with concretionary sands; the fossils are shells of the genera *Nerinæa*, *Lucina*, *Modiola*, &c. with numerous fragments of the leaves of ferns (especially of *Pecopteris polypodioides*), and of cycadeous plants. These beds are regarded by Captain Ibbetson and Mr. Morris, as the equivalents of the carbonaceous shales of Scarborough and Gristhorp bay; in fact, as the seaward extension of those fluvio-marine strata; those of Stonesfield appear to have been synchronous, but deposited farther from land, in the depths of the oolitic ocean.

23. Carboniferous Oolite of Brora.—Carboniferous fluvio-marine deposits of a similar character, and of the same age as those above described, occur in the north of Scotland.* At Brora, on the south-east coast of Sutherlandshire, intercalated between oolitic calcareous strata and Lias shale, there is a series of deposits, consisting of layers of coal interstratified with sandstones and shales, containing remains of terrestrial plants, and a few fresh-water shells and cyprides. And in the neighbourhood of Elgin, and on the north-east coast of the Isle of Skye, shales and sandstones, with impressions and remains of similar plants, are met with, superimposed on the Lias.†

The calcareous strata of Brora contain numerous fossils

* For a general view of the geological phenomena of Scotland, I would strongly recommend the reader to obtain the charming and instructive little volume by Mr. James Nicol, Curator of the Geological Society of London, entitled, A Guide to the Geology of Scotland, 1844.

† Sir R. Murchison, in Geol. Trans. vol. ii. p. 293.

identical with those of the middle and inferior oolite of the eastern moorlands, and north-eastern coast of Yorkshire; and as in that district, the lower beds of the Coral-rag pass into a yellowish sandstone, beneath which is shale containing belemnites, and from under this bed the carboniferous strata emerge. This series of deposits rests on Lias shale.* Many of the fossils are identical with those of the pier-stone of Scarborough, which there overlies the main coal-seams.

The fossil plants are for the most part of the same type as those of Yorkshire, and are associated with shells of the genera *Cyclas, Unio, Paludina*, and species of *Tellina, Perna*, &c.: cases of the *Cypris granulosa* (p. 405) also occur in profusion. Scales and teeth of numerous small ganoid fishes, of genera common in the Oolite, (*Hybodus, Lepidotus, Acrodus*,) abound in some of the layers of clay: fragments of plates of Turtles are, I believe, the only reptilian relics hitherto observed.

These carboniferous deposits have evidently had the same origin as those on the Yorkshire coast, in which Uniones and Cyprides are associated with Ferns, Zamiæ, Thuyites, and other terrestrial plants.† Taken as a whole, the fluvio-marine intercalations of the oolite must be regarded as local accumulations of the spoils of the land, transported into the bed of the ocean by the agency of rivers and currents; the presence of coal depending on the streams

* The interesting Memoir of Sir R. Murchison on the Coal-field of Brora should be referred to for details. Geol. Trans. vol. ii.; also, a valuable paper by Mr. Robertson on the same, Geological Journal, vol. iii. p. 113.

† Mr. Bakewell has described a coal-mine, in which seams of coal are intercalated with calcareous strata, in a mountain-range near the Lake of Annecy in Savoy; and which, from the shells in the limestones, he considered as belonging to the same period as the carboniferous oolite of Yorkshire. See Travels in the Tarentaise, vol. i. p. 185.

being largely charged with vegetable remains. They belong to a period long antecedent to the deposition of the Wealden.

24. CARBONIFEROUS OOLITE OF EASTERN VIRGINIA.—One of the most remarkable features in the geology of the United States of North America, as contrasted with that of Europe, consists in the entire absence of deposits that can be regarded as the equivalents of any of the members of the Oolitic system. With but one exception, no natural records remain of the vast interval of time that must have elapsed, between the close of the Triassic and the commencement of the Cretaceous epoch. Some time since, it was suggested by Professor W. B. Rogers, that an extensive coal-field in Eastern Virginia * belonged to the oolitic period; and this opinion has been confirmed by the recent investigations of Mr. Lyell. This coal-field is about twenty miles from north to south, and from four to twelve miles in breadth from east to west. It is situated in a granitic region, and the lowermost bed of coal rests upon granite. Quartzose grits, sandstones, and shales, are intercalated with the coal, as in the carboniferous system of Europe. Beds of rich bituminous coal, one being in some places from thirty to forty feet thick, occur in the lower division.

The fossil plants resemble those of the Oolite of Yorkshire, (*Pecopteris Whitbiensis*, *Equisetum columnare*, some species of *Zamites*, *Tæniopteris*, *Neuropteris*, &c.) differing specifically, and most of them generically, from those of the older coal formations. From the upright position of many of the Equiseta, Mr. Lyell infers that the vegetables which produced the coal grew on the spot where they are now

* There are two coal-fields in the State of Virginia; the remarks in the text exclusively refer to that near Richmond, the coal measures in Western Virginia belong to the ancient carboniferous system.

found, and that the strata were formed during alternate subsidences and elevations of this part of Virginia. They contain shells and fishes (*Tetragonolepis*, and a new genus, *Dictyopyge* of Sir P. Egerton, *Catopterus* of Mr. W. C. Redfield,*) related to European Liassic species. Mr. Lyell regards this coal as of the age of the Inferior Oolite and Lias: and if this opinion be correct, these deposits are the first ascertained equivalents of any of the oolitic series hitherto discovered in North America.

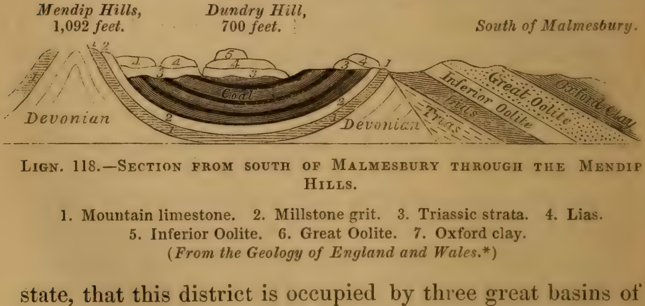
25. The Lias.—The lowermost group of the Oolite or Jurassic system termed the Lias, consists of stratified blue and grey marls, clays, and limestones, amounting in total thickness to from five hundred to one thousand feet, and abounding in many peculiar fossils. The principal lithological features are the uniform aspect, and distinctly stratified character of the limestones and intervening argillaceous layers; the most constant subdivisions are those mentioned in the table, p. 493.

It may be stated in general terms, that the Lias of England extends along the western escarpment of the Oolite, forming a district which presents an exceedingly variable surface, occasioned by the disruption and subsequent denudations which the strata have undergone. The course and extent of these deposits from Yorkshire to the Dorsetshire coast, are admirably described by Mr. Conybeare,† from whose work the following abstract is derived.

The Lias, from its northernmost limits on the Yorkshire coast, where it underlies the strata of the eastern moorlands, passes to the south of Whitby and to the east of York, and crosses the Humber, near the junction of the Trent and Ouse; stretching onward beneath the low oolitic range of Lincolnshire, it extends to the Wold hills, on the

* Geological Journal, vol. iii. Pl. VIII.
† Outlines of the Geology of England and Wales, p. 261.

borders of Nottingham and Lincoln, to Barrow-upon-Soar; whence it continues, accompanying the escarpment of the inferior and great oolite, through Nottingham, Warwick, and Gloucester. Its whole course, to within a few miles south of Gloucester, is remarkably regular, presenting an average breadth of about six miles, bounded on the south-west by the Oolite, and on the north-west by the Red marl, which will hereafter be described. Beyond Gloucester, its range becomes intricate; its eastern limit accompanies the oolite through Somersetshire to Lyme Regis; but the western is very irregular, feathering in and out among the coal-fields, which occur towards the estuary of the Severn, and the upper part of the Bristol Channel, Gloucestershire, Somersetshire, Monmouthshire, and Glamorganshire, and attended with numerous outlying or detached masses. To render the course and position of the Lias in this part of England intelligible, it is necessary to



Lign. 118.—Section from south of Malmesbury through the Mendip Hills.

1. Mountain limestone. 2. Millstone grit. 3. Triassic strata. 4. Lias. 5. Inferior Oolite. 6. Great Oolite. 7. Oxford clay.
(*From the Geology of England and Wales.**)

state, that this district is occupied by three great basins of the coal formation, encircled by the underlying and subjacent limestones, and Devonian sandstones; one of which is shown in the annexed section.

* The inclination of the strata is very much exaggerated in this diagram, in consequence of the difference in the horizontal and vertical scales, necessarily adopted to comprise the section in a small space.

The edges of these basins consist of strata thrown up at a high angle, and often nearly vertical, forming bold and precipitous ranges of hills ; in the valleys, horizontal layers of lias, with subjacent beds of red marl, are seen lying unconformably upon the highly inclined coal measures (*Lign.* 118, 3, 3, 3). I shall recur to this subject hereafter, and now only observe, that the Lias appears beneath the Oolite through the south-east of Somersetshire, and passes into Dorsetshire, where the overlying Greensand conceals it beneath the high range of the Black Down hills.

At Lyme Regis it forms a range of cliffs, about four miles in length, and may be traced till it gradually sinks beneath the Inferior Oolite. The skeletons of large marine reptiles (*Ichthyosauri* and *Plesiosauri*), for which the Lias is celebrated, have principally been found in the cliffs at Lyme, Watchett, Westbury, and Whitby, where the natural sections, formed by the action of the waves, well display the characters of the strata, and afford abundance of fossil remains. The Lias appears in the Western Isles of Scotland, and on the north-east coast of Ireland.

In the north and south-east of France, and over a large area in Germany, the Lias, with its peculiar fossils, accompanies the Oolite. One species of Gryphite (*Gryphea incurva*, *Lign.* 111, *fig.* 6) which is so abundant in the Liassic strata of England, on the Continent forms a limestone (*Calcaire à gryphites*), which, like the Sussex marble, is composed of shells cemented together by a calcareous paste. In Wirtemberg the Lias presents the usual characters of that of England, and contains remains of Ichthyosauri and other saurians.*

In the valley of the Arve, in Switzerland, the Lias clays are of great thickness ; and owing to the ancient effects of

* See Dr. Jaeger's work, Uber die Fossile Reptilien welche in Wurtemberg aufgefunden worden sind. Stutgard, 1828.

igneous agency everywhere apparent in the Alps, have a schistose character, strongly assimilating them to the primary slates.

In Russia oolitic deposits cover detached districts, from the Icy Sea to the Caucasus in the south; and in Russia Proper, there are shales and sands referable to the middle or Oxford oolite; a characteristic species of ammonite (*A. biplex*) of the Portland rock has been found both in Russia and Poland.* In the Himalayahs, argillaceous beds occur, which contain fossils analogous to those of the Lias of Europe; and from other localities in northern and southern India, one belemnite and two ammonites identical with Oxford clay species, have been found in deposits apparently of the Jurassic epoch.

26. ORGANIC REMAINS OF THE JURASSIC SYSTEM.—The fossils discovered in the Oolitic and Liassic strata amount to many hundred species, and it is impossible in a work of this nature to give even a brief summary of these organic remains; it must suffice to offer a few general remarks on the nature of the fauna and flora of the sea and land, during the vast period of time which the accumulation of sediments of such extent and thickness must have required.

Vegetable remains.—Several species of fucoid plants, and upwards of forty species of terrestrial vegetables, have been determined. The latter, with the exception of a few ferns and palms, consist of cycadeous plants (i. *Zamiæ*, *Mantelliæ*, &c.) and coniferous trees; constituting a flora analogous to that which now prevails in the maritime

* Sir R. Murchison.

† I would refer to Prof. Phillips' tables of fossils in the Encyclopædia Metrop. art. *Geology*; to Sir H. De la Beche's Manual of Geology, and to Mr. Morris's British Fossils, for lists of the fossils found in the British Oolite and Lias; and to the beautiful work on the organic remains of the "*Terrains Jurassiques*" by M. D'Orbigny. See also my Medals of Creation.

districts of the West Indies, New Holland, and the Cape of Good Hope, &c. A large species of Marestail (*Equisetum columnare*) is abundant in the Carboniferous Oolite; and in Yorkshire so many of these plants occur in an erect position, that it is supposed they must have grown on the spots they now occupy: we shall recur to this fact hereafter.

One of the most remarkable vegetable fossils discovered in this formation in England, is the fruit of a tree allied to the Pandanus or Screw-pine, from the lower oolite of Charmouth in Dorsetshire.*

Fragments of trunks of coniferous trees of the Araucarian type are found throughout the Jurassic formation; and, as we have already stated, the last bed of the Oolite, when elevated above the waters, was clothed with pine-forests (vol. i. 387).

The quantity of drift wood in a carbonized state, but not converted into coal, is very considerable in the argillaceous strata. In the Oxford clay, at Trowbridge, my son found masses of wood in abundance; oysters, terebratulæ, and other shells, were often adherent to the fragments of trunks and branches of trees, which had evidently been drifted from a distance into the bed of the sea. Much of this wood was soft and flexible when first exposed, and when dry, burnt with a bright flame. In the Lias of Whitby, Lyme Regis, and other localities, the wood is often calcareous, and admits of a fine polish: occasionally silicified masses are met with.†

27. Zoophytes and Radiaria.—Of corals and other polypiferous zoophytes hundreds of species abound. The reefs of coral, constituting the Coral-rag, have already been described. In some parts of Germany the Coral-rag is largely developed, and all the corals are silicified in

* Dr. Buckland's Bridgwater Essay, vol. ii. pl. 63.

† Beautiful specimens of the fossil wood and plants from the Lias and Oolite are exhibited in the British Museum.

certain localities: this is especially the case at Nattheim, near Heidenheim, whence exquisite specimens of Lithodendron have been obtained.

In the beds of chert in the Oolite of Tisbury in Wilts, shells and corals are found in a beautifully silicified state, particularly a species of Astræa (*A. Tisburiensis*). Large silicified masses of this coral are met with, which, on being cut and polished, display the intimate structure of the original, and form a highly ornamental material for the jewellers and lapidaries. A matchless specimen of the soft parts of a Trigonia, transmuted into silex, was obtained from Tisbury by the late Miss E. Benett, and is now, with the greater part of the collection of that lady, in the possession of Mr. Wilson of Philadelphia.*

The Crinoidea, or lily-shaped animals, are equally abundant, and are often found in an admirable state of perfection. Whole slabs of many of the Lias shales are covered with Pentacrinites, frosted with brilliant pyrites, and lying in relief on the stone, as if spread out on the sea-sand.†

Of *Echinites* upwards of sixty species, and of Star-fishes several genera, comprising many species, have been determined. Some splendid Star-fishes from the Yorkshire Oolite and Lias are figured in the London Geological and Palæontological Journal, pl. 17, (*Asterias arenicola*), and pl. 19, 20 (*Ophiuræ*).

28. MOLLUSCA.—The shells, both of testaceous and conchiferous mollusks, amount to many hundred species. Of the *Cephalopoda*, as Nautili, Ammonites, Belemnites, Sepiadæ, &c. several hundred species, belonging to numerous genera, have been figured and described.‡

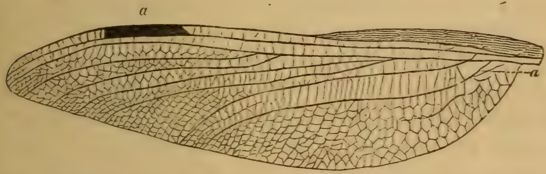
* Figures and a description of this extraordinary British fossil will be given by Mr. Charlesworth in the Palæontological Journal, from drawings by Mr. Dinkel.

† See Brit. Mus. collection.

‡ See Sowerby's Mineral Conchology, and the works before referred to.

The state of perfection in which the animals allied to the Cuttle-fish occur in the Lias, and also in the clays of the Oolite, especially in the Oxford clay of Wiltshire,* is most extraordinary. The soft parts of the body and arms, the capsule of the globe of the eye, and the ink-bag still retaining its inspissated secretion, are often found in their natural position, and distinctly recognisable. This state indicates a rapid imbedding of the animals while in their natural element.†

29. CRUSTACEANS AND INSECTS.—Numerous genera of Crustaceans and Insects have been collected: the museum of the late Count Munster was celebrated throughout Europe for the magnificent series of remains of this kind which it contained.



LIGN. 119.—FOSSIL WING OF A SPECIES OF DRAGON-FLY; FROM THE LIAS OF BIDFORD, WARWICKSHIRE. *(Nat. size).*‡

a, Spot on the margin of the wing.

(*Æshna Liassina, of Mr. Strickland.*)

Species allied to the Shrimps, Prawns, Lobsters, and Crabs, have been found in great perfection at Solenhofen, Pappenheim, &c.; a species of Limulus, or of some allied form (*Eryon Cuvieri*), occurs in an exceedingly perfect state.

* See the London Geological and Palæontological Journal, No. 2, Pl. XV. XVI., for figures of some remarkable specimens in the cabinet of Mr. Channing Pearce.

† See Dr. Buckland's Bridgwater Essay, for exquisite figures of the shells and soft parts of Cephalopoda.

‡ By H. G. Strickland, Esq.—Mag. Nat. Hist. vol. iv. p. 301.

A beautiful Dragon-fly, from Solenhofen, in the cabinet of the Marquess of Northampton, is figured in Medals of Creation (vol. ii. p. 574). In England, the Lias, Stonesfield slates, and Forest marble, have alone yielded fossil insects. Among the specimens found in the Lias, is a wing of a very large Dragon-fly, which Mr. Strickland states closely resembles the recent species in the general arrangement of the nervures, and is nearly related to the genus *Æshna* (*Lign.* 119). In this fossil an opaque spot (*a*) exists on the anterior margin of the wing, as in most of the living Libellulidæ.

Mr. Brodie has figured and described numerous fossil insects from the Oolite of England,* comprising Coleoptera, Neuroptera, Hemiptera, and Homoptera. The wings of insects allied to the recent genus *Panorpa*, have been found in the Lias of Wainlode Cliff, on the banks of the Severn.†

As in the case of the insects of the Wealden, the several hundred specimens that have been discovered in the lower beds of the Lias, all belong to forms that inhabit temperate climates, and present a remarkable affinity to existing families; so that in one instance only has Mr. Westwood, the distinguished entomologist, ventured to propose a new generic name.‡

30. FISHES.—All the fishes of the Oolite are referable to

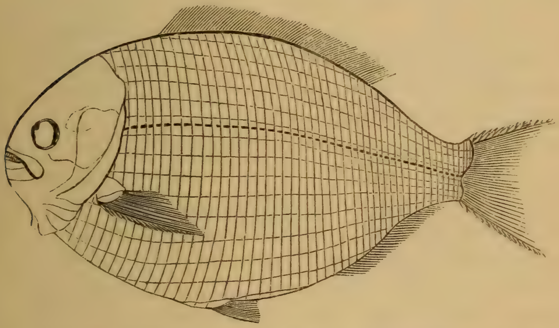
* History of Fossil Insects, p. xiv. In this work will be found an account of all the localities in which insect remains have been discovered in the secondary rocks of England. The descriptive sections are highly instructive. See also Dr. Buckland's Bridg. Essay; and Medals of Creation, vol. ii.

† See Medals of Creation, vol. ii. p. 576. The transverse lines on the wings are not fractures, as Mr. Brodie supposes, (*Fossil Insects, note to* p. 59,) but nervures; the figures were accurately drawn under the microscope by Mr. Woodward.

‡ Mr. Strickland, on the results of recent researches into the fossil insects of the secondary formations of Britain: Brit. Assoc. Reports for 1845, p. 58.

extinct genera, and essentially differ, as a whole, from those of the cretaceous epoch. Teeth, scales, dorsal spines, and other remains of species of the genera *Lepidotus*, *Acrodus*, *Hybodus*, *Leptolepis*, *Psammodus*, *Ceratodus*, &c. are abundant in many of the strata.*

At the base of the Lias, and separating the lowermost shale from the uppermost Triassic bed beneath, there is a layer of coarse detritus, a few inches thick, commonly known as the *Bone-bed*, from the immense quantities of



LIGN. 120.—RESTORED FIGURE OF THE DAPEDIUS OF THE LIAS.

(*One-sixth the natural size. By M. Agassiz.*)

water-worn bones, teeth, and coprolites of fishes, which it contains. It is, in fact, an aggregation of mud, sand,

* See Medals of Creation, vol. ii. for figures and descriptions. In the British Museum there is an extensive collection of the fossil fishes of the Lias and Oolite, and the scientific and English names are affixed to each specimen: it only requires the localities to be added to render the arrangement perfect. The eminent naturalist, Charles König, Esq., who has so long presided over this noble gallery of organic remains, deserves the highest praise for the admirable manner in which the fossils are displayed and classified.

and the debris of fishes and reptiles. Aust Cliff, on the Severn, near Westbury, in Somersetshire, is a well-known locality for the fossils of this remarkable deposit. By some geologists this bone-bed is included in the Trias, and by others in the Lias. A similar stratum occupies the same geological position in Germany, and contains organic remains of a like nature ; specimens of teeth of fishes of the genus *Ceratodus* (Med. Creat. p. 618), are very frequent in this bed.

Among the Ichthyolites that prevail in the Lias, the scales and teeth of a genus of Ganoids called *Dapedius* (*Lign.* 120), are especially abundant, and entire specimens of the fish are often met with. I am led to notice this genus more particularly, that your attention may be directed to a remarkable modification of structure observable in the Ichthyolites of the more ancient deposits, which will hereafter come under our examination. The Dapedius belongs to that division of the *Lepidoids* in which the tail is *homocercal*, or equal-tailed; while in all the genera of the palæozoic strata (p. 203) the tail is *heterocercal*, or unequal-lobed.* But few of the existing genera of fishes have this condition of the caudal fin, while it is found in almost every fossil species below the Triassic deposits.†

31. Reptiles of the Jurassic system.—The prevalence of animals of the reptile class during the Oolitic era, was incidentally alluded to in the course of our previous observations on the organic contents of the different members of this extensive formation. From the lowermost stratum, the bone-bed of the Lias, to the uppermost layer of the Portland stone, the remains of

* See Medals of Creation, p. 604.

† It is worthy of remark, that in the embryotic state the tail in all fishes is heterocercal, and passes into the homocercal type in the progress of development in those species which have this form of the caudal appendage when arrived at maturity.

extinct reptiles have been found more or less abundantly in every deposit. Upwards of fifty species, belonging to several genera, have been determined by the various naturalists who have treated on this subject. Those of the British strata have been accurately investigated and described by Professor Owen, whose memoir, in the Reports of the British Association for 1840 and 1841, presents a masterly and comprehensive view of the fossil reptiles at that time known. As I shall have occasion to recur to this subject in the sequel, it will be sufficient in this place briefly to enumerate the principal kinds hitherto discovered in the Oolite and Lias.

In addition to the reptiles of which remains have been found in the Chalk and Wealden, namely the Megalosaurus (*ante*, p. 421), Pœcilopleuron (p. 417), Cetiosaurus (p. 412), Streptospondylus, Pterodactylus, Ichthyosaurus, Plesiosaurus, — and of some of these, especially of the two last-named genera, numerous species abound in the Lias, and Oolite,—several other Crocodilian and Lacertian reptiles, with peculiar osteological modifications, also occur. These are the Teleosaurus, Steneosaurus, &c.* which are characterized by their long narrow muzzles, sharp-pointed teeth, short forelegs, imbricated scales, and doubly concave or flat vertebræ: their relics are chiefly found in the middle and lower Oolite.

The most remarkable circumstance relating to the Ichthyosauri and Plesiosauri that swarm in the Lias, is the connected state in which all the bones of the skeleton occur. The entire osseous frame-work, from the extremity of the snout to the last vertebra of the tail, often remains entire, or but very little displaced from its natural position; even the bones of the paddles, with their cartilaginous appendages, are in some instances preserved.† The indigestible portion of the food of these carnivorous marine

* See Medals of Creation, vol. ii. p. 723. † Ibid. p. 713.

reptiles, as the scales, teeth, and bones of fishes, and their coprolites, are frequently met with in the abdominal cavity.* These facts show that the carcasses of these animals were imbedded in the soft mud at the bottom of the sea, without having been exposed to the action of the billows, or to long transport by rivers or currents. The Wealden fossils present a striking contrast in this respect ; for although bones of plesiosauri are by no means uncommon in that formation, no two have ever been observed in contact, and all the specimens that have come under my observation are water-worn.

In the Kimmeridge Clay, the relics of a very large marine lizard allied to the Plesiosaurians, but distinguished by certain osteological characters, have been met with : this extinct reptile is named Pliosaurus. Bones of Flying-Dragons, or Pterodactyles, occur more abundantly in the Oolite and Lias than in any other series of deposits ; eleven species have been found in the Solenhofen quarries alone. In the Stonesfield slate (*Pterodactylus Bucklandi*), and in the Lias of Lyme Regis (*P. macronyx*), bones of one species, and a considerable part of the skeleton of another, have been discovered. The Mammalians of Stonesfield have already been noticed (*ante*, p. 510).

The general character of the Jurassic or Oolitic formation, as derived from its organic remains, is therefore that of a series of oceanic deposits, accumulated in a depression of great extent, through a period of immense duration. The sea teemed with marine animals, belonging to genera and species most of which became extinct before the Tertiary epoch ; and with these were associated multitudes of peculiar Reptiles. The dry land, as attested by the remains drifted into the basin of the sea, was inhabited by numerous reptiles, and a few marsupial mammalia, and was clothed with tree-ferns, palms, cycadeous plants, and coniferous trees.

* Consult Dr. Buckland's Bridgwater Essay.

LECTURE V.

PART II.—THE TRIAS AND PERMIAN FORMATIONS.

1. THE TRIAS AND PERMIAN FORMATIONS.—Beneath the Lias there is a series of strata, many hundred yards in total thickness, which was formerly known in geology as the *Saliferous*, or *New Red Sandstone Formation*, and divided into two groups, namely the Upper, and Lower.* But recent investigations having shown, that of the fossils found in the lowermost group, not a single species is known in the upper series, nor in any newer strata, this system is now

* As in the former editions of this work : and in the Medals of Creation, vol. i. 39.

separated from the former, and regarded as the first, or terminal group, of the *Palæozoic* or ancient secondary; while the Upper New Red is ranked as the lowermost of the medial secondary formations.* The name of *Trias*, or Triassic System, by which the Upper New Red is now distinguished, relates to the well-marked triple subdivision of this series in Germany, and has been adopted to avoid confusion from the restricted application of the old term. The synonyme of *saliferous*, refers to the immense beds of rock-salt which alternate with the red marls in Cheshire, and other parts of England. The following table shows the characters and order of succession of the principal deposits:

The Triassic or New Red Formation.

(Comprising the Keuper, Muschelkalk, and Upper Bunter, of the German geologists.)

1. Variegated red, bluish, and white marls, with gypsum, and immense beds of rock-salt.
2. Variegated red and white sandstone.
3. Conglomerates formed of the detritus of the older sedimentary rocks.
4. Red mottled sandstones, and marls.

Total thickness, about 300 yards.

The Permian or Magnesian Limestone Formation.

(Comprising the Lower Bunter, Zechstein, and Roth-todt-liegendes,† of the Germans.)

1. Red and white marls.
2. Magnesian limestone (*Zechstein*); white, red, or yellowish limestone, with a large proportion of magnesia, in thick beds, with marine organic remains.

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* See the "Synoptical Arrangement," p. 203.

† *Roth-todt-liegendes*, signifying, red-dead lyer, is a German mining term, denoting that the copper of the upper beds has died out, this layer not being metalliferous.

3. Marl slate, in thin layers, containing reptiles and fishes. The *Keuper schiefer*, or Copper schist of Mansfeld.
4. Marls and variegated sandstones, with sands and clays of variable thickness and character.

Total thickness, 100 yards.

From this tabular view, the Trias and Permian systems are seen to consist of variegated blue and red marls and sandstones, magnesian limestones, and conglomerates, more or less coloured with peroxide of iron; the upper group containing beds of salt and gypsum, and the lower, calcareous rocks, having in their composition a large proportion of magnesia. As a whole, the strata are comparatively scanty in organic remains; but in some localities plants of several genera and species,—ammonites, nautili, belemnites, and other marine shells,—and Plesiosauri and other reptiles are met with; certain species and genera being peculiar to each system.

2. Geographical Distribution of the Trias and Permian.—For the sake of conciseness I shall comprise both systems, in the following brief notice of their geographical distribution.*

From the river Tees (*see the map*, Pl. I. p. 462), on the Yorkshire coast, the line of their emergence from beneath the Lias, forms their eastern boundary; and they extend nearly parallel with the western branch of that formation to the Dorsetshire and Devonshire coasts, near Lyme Regis, Sidmouth, and Torbay.† But the district of which they form the subsoil, is exceedingly variable in breadth, from the great extension of its western limits. This arises from the saliferous being the last of the nearly horizontal con-

* In the map, Plate I. the Trias and Permian are both included under the term *Triassic*, and denoted by the same colour and number (4).

† This account of the course of the Trias is principally derived from the "Geology of England and Wales."

formable beds of the eastern and southern counties: the underlying strata being thrown up at various and often considerable angles, into lofty groups and chains of mountains, which appear like so many islands amidst the great plain of Red-marl (see section of the Mendips, *Lign.* 118). From Yorkshire to Nottingham they constitute a tract of a somewhat uniform breadth of twelve miles. In many parts of Nottinghamshire veins of gypsum are abundant in the marls; and a quartzose gravel, consolidated into a breccia or conglomerate, covers a considerable area, and forms the hill on which Nottingham Castle is situated. Passing on to Derby and Leicester, the Red-marl spreads into a vast plain, which occupies nearly the whole of Cheshire, and the southern part of Lancashire and Shropshire, and is the grand depository of rock-salt. The Dudley coal-field is surrounded by Triassic strata, which extend to Cheshire on the one hand, and to Leicestershire and Yorkshire on the other.* The Magnesian limestone range of the Permian in the south of England, forms a natural terrace from 400 to 500 feet above the level of the sea, its escarpment being to the west.†

On the Continent this group, with some occasional variations in the strata, may be traced opposite the Devonshire coast, skirting the transition rocks of Brittany, and to the west underlying the Jura limestone, and containing beds of gypsum and salt. It encircles the Vosges and the German chain of the Black Forest in the south, forms a zone on either side the Alps, and flanks both sides of the Carpathian mountains. It spreads over an extensive area in central Germany, and prevails in the north and east of European Russia; the great extension of the Magnesian

* See a brief notice of the Red-marl near Leicester in Medals of Creation, vol. ii. p. 934.

† Professor Phillips.

limestone series, over the ancient kingdom of Permia, suggested the present geological name of this formation.

The Trias of Germany, distinct in its triple characters, is well developed in Bavaria and Wirtemberg. Immediately beneath the Lias is the series termed the *Keuper*, which consists of variegated red and green marls and sandstones, containing intercalations of salt and gypsum, as in England. This group is superimposed on a fine cream-coloured shelly limestone, called the *Muschelkalk*, which abounds in organic remains; especially in that beautiful extinct crinoidean, the *Lily encrinite* (*Lign.* 124), which is exclusively found in this bed; the equivalent of the Muschelkalk is not known in England. The lowermost series is the *Bunter sandstein*,* consisting of variegated sandstones and marls, resembling those of the upper group.

In the United States of North America the Trias occupies the valley of the Connecticut, from Newhaven to the north line of Massachusetts. It contains carboniferous shale, with plants belonging to the fossil genera, *Calamites*, *Lycopodites*, *Voltzia*, and *Fucoides*; and bituminous slate, with fishes resembling those of the Trias of Europe.† These strata are invested with an extraordinary degree of interest, from the abundance and variety of the foot-prints of unknown animals with which the surface of some of the laminated sandstones are impressed; a phenomenon we shall presently examine.

There does not appear to be any deposits in North America that can be regarded as the equivalents of the Permian: in that country the Palæozoic series terminates with the Coal, for the zone of Triassic deposits is the only indication of

* Variegated or spotted sandstone.

† Review of the Geology of Massachusetts, by Professor Hitchcock, of Amherst College. This work is alike honourable to the eminent author, and the enlightened government by whose direction it was undertaken.

sedimentary rocks of an age intermediate between the carboniferous and cretaceous formations; with the solitary exception of the Virginian coal-field previously described (p. 520).

3. Rock-salt and Brine Springs of the Trias.—In England, the Trias is the chief repository of salt or chloride of sodium: and brine-springs, which are subterranean streams of water impregnated with salt from percolating through saliferous strata, are abundant in the great plain of the red marls and sandstones of Cheshire. The salt, however, is not uniform in extent, but occupies limited areas. The saliferous strata of Northwich present the following series:—

		Feet.
1.	Uppermost calcareous marl . . .	15
2.	Red and blue clays	120
3.	Bed of rock-salt	75
4.	Clay, with veins of rock-salt . .	31
5.	Second bed of rock-salt	110

Droitwich, in Worcestershire, which is situated nearly in the centre of the county, has been celebrated for the production of salt from its brine-springs, from the time of the Romans; and ever since, this inexhaustible fountain of saline water has continued flowing up, and yielding salt in undiminished quantities.* It is probable that the manufacture is coeval with the town itself; but it was not till the year 1725, that the strong brine for which it is now famous, was discovered; from one spring alone, the enormous quantity of a thousand tons of salt are obtained per week.

At a distance of from thirty or forty feet below the surface, there is a bed of hard gypsum, about 150 feet thick: through

* The Romans imposed a tax on the Britons who worked the Droitwich salt mines, and made salt a part of the pay of their soldiers' *salarium*, or salary. Hence the custom of asking for salt at the Eton Montem.—*Geology of England and Wales*, p. 282.

this a small hole is bored to the river of brine, which is in depth about twenty-two inches, and beneath which is rock-salt. The brine rises rapidly through the aperture, and is pumped into a capacious reservoir, whence it is conveyed into iron boilers for evaporation; it is supposed to be stronger than any other in the kingdom, and contains above one-fourth part its weight of salt. One of the shafts is sunk to a depth of nearly 500 feet, and passes through four layers of salt, 85 feet in aggregate thickness. Some of the beds of salt in Cheshire are from 70 to 120 feet thick. A red sandstone, containing vegetable remains, forms the foundation rock of the saliferous deposits of England.*

4. Origin of Rock-salt.—The origin of these enormous subterranean beds of rock-salt is as enigmatical as that of the saltness of the waters of the ocean. But deposits of salt, though prevailing in England, Hungary, and Poland, in the formation under examination, are not confined to any particular group of strata. The celebrated salt-mines of Galicia belong to the tertiary formations (*ante*, p. 284); while, in the State of New York, salt and gypsum, with variegated marls, are found in the middle of the Silurian system.† It is to be remarked, that deposits of chloride of sodium are almost always accompanied with layers and intercalations of gypsum; and the circumstance of two powerful acids, the sulphuric (in the gypsum or sulphate of lime), and the muriatic (in the chloride of sodium), being

* For a graphic account of the salt-works at Droitwich at the present time, see Mr. Hugh Miller's "Impressions of England and its People," p. 179.

† In the middle of the horizontal Silurian rocks of the State of New York, there is a formation of red, green, and bluish grey marls, with beds of gypsum, and occasional salt springs, the whole being from 800 to 1000 feet thick, and undistinguishable in mineral character from parts of the Trias of Europe.—*Mr. Lyell's Travells in America*, p. 54.

so largely and uniformly present, seems to indicate a common origin; both occur abundantly as volcanic products. In a more advanced state of chemical science, this fact may probably tend to the elucidation of the question under consideration.

The gypsum associated with rock-salt, is considered by several eminent observers to be anhydrous, that is, entirely free from water, before exposed to moisture. The great beds of gypsum that occur with rock-salt at Bex, in Switzerland, were found by M. Carpentier to be anhydrous when laid open to the atmosphere. Hence Mr. Bakewell suggests that the consolidation of the salt and gypsum, must have been effected in such cases by heat, for there is no conceivable mode of aqueous deposition that could form anhydrous gypsum.* The red colour of the salt and marls is occasioned by oxide of iron, which may have been derived from decomposed trap rocks.

That many of the deposits of salt may have originated simply from the evaporation of sea-water pent up in lagoons, lakes, or inland seas, is a generally received, and not improbable supposition; but the absence of marine organisms, of any kind, has been regarded as a formidable objection to this hypothesis.† Another difficulty presents itself in the enormous thickness of many of the beds of salt; which, if considered as the solid residuum of sea water, must have required a body of fluid inconceivably great; unless we suppose the seas of those ancient periods to have

* I would refer to Mr. Bakewell's Introduction to Geology, (5th edit. p. 289,) for a luminous review of this problem, and a full account of the most important deposits of salt.

† It cannot however be with certainty determined, whether the absence or paucity of fossils in a deposit is owing to an actual reduction of the amount of life in the seas of a given area, or to the mineral character of the strata not having been favourable to the preservation of organic remains.

contained a much larger proportion of saline ingredients than the present,—an inference for which there are no reasonable grounds whatever. If we imagine successive subsidences of a given area to have taken place, the alternations of beds of marls with layers of salt of variable thickness, may be explained; but the difficulties above mentioned remain in full force. As the chlorides of sodium and gypsum* are often sublimed from volcanic vents, an igneous origin has been ascribed to many of the beds of salt and sulphate of lime. Gypsum is unquestionably, in most instances, a metamorphic rock; for sulphurous fumes acting on beds of clay containing shells, convert the lime into selenite, and limestone into fibrous and rock gypsum. Many tertiary gypseous deposits have evidently originated from this cause: but crystals of gypsum are also abundantly found in beds containing pyrites, from the decomposition of the sulphuret of iron, and the formation of sulphate of lime from the action of the liberated sulphuric acid on the calcareous materials.† In many parts of Sicily, vapours charged with sulphuric acid are constantly emanating from vents or fumaroles, as they are termed, and throw down large deposits of sulphur and gypsum; and the fumes of sulphur and boracic acid escape in such quantities, that the peasants put pots, and often bee-hives, over the fumaroles, and thus collect abundance of sulphur and boracic

* Gypsum, or sulphate of lime, consists of sulphuric acid, 46·31; lime, 32·90; and water, 20·79. The massive gypsum is called *Alabaster;* the transparent gypsum, *Selenite;* powdered calcined gypsum forms *Plaster of Paris.* The fibrous gypsum has a silken lustre, and is used for ear-rings, brooches, and other ornaments. Fibrous gypsum of great beauty occurs in Derbyshire: veins and masses of this substance abound in the red marls bordering the valley of the Trent.

† Recent railway embankments of shelly clays often exhibit this phenomenon, and are liable to give way from their consolidation being thereby prevented.

acid.* In Tuscany, boracic acid is obtained from jets of vapour which force their way through secondary rocks in contact with serpentine.†

The connexion between volcanic action and the formation of gypsum, seems also pointed out by the fact, that, in North America, where volcanic rocks are not associated with the coal measures, there are no beds of gypsum: but in Nova Scotia, where igneous rocks are interpolated beneath the coal, there are extensive gypseous deposits.‡ Mr. Lyell, after a careful review of the phenomena exhibited by these gypsiferous strata, expresses his conviction, that the production of gypsum in the carboniferous sea was intimately connected with volcanic action, whether in the form of stufas or heated vapours, or of hot mineral springs, or some other effects of sub-marine igneous eruptions.

I may, also, remark, that the variegated appearance of the marls,—red, pink, blue, yellow, dun, &c.—of the Trias, seems to have been produced by the chemical effects of vapours or fluids charged with sulphuric or chloric acid; at least the same change is induced on the tertiary marls of the Lipari Isles, by the gaseous emanations and vapours of the fumaroles and hot springs.

5. THE CHELTENHAM WATERS.—In certain localities where the marls of the Trias are covered by other beds, and the saline springs force their way to the surface through the superincumbent deposits, chemical changes take place in these solutions of chloride of sodium, which thus acquire

* Mr. Playfair informed Dr. Buckland, that, during an eruption of Vesuvius, sulphuret of copper was ejected: and Mr. Fox states that sulphuret of copper may have been deposited from solution in boiling water.

† See a highly interesting Memoir on the Geology of some parts of Tuscany, by W. J. Hamilton, Esq. M.P. Geol. Journal, vol. i. p. 274.

‡ See Geological Journal, vol. iii. p. 257.

other properties, and become what are termed mineral waters; such is the origin of the celebrated Cheltenham waters.*

The town of Cheltenham is built on Lias clays and marls, beneath which, but at a great depth, lie the Triassic deposits, the reservoir of the rock-salt and brine-springs, whence the mineral waters have their origin, and derive their saline ingredients; but these undergo various modifications in their passage to the surface through the superincumbent beds of Lias, which are full of iron pyrites, and sulphate of lime. From the analyses of these

LIGN. 121.—SECTION OF THE LIAS AT CHELTENHAM.

(From Sir R. I. Murchison's Sil. Syst.)

1, 1. Red marl. 2, 2, 2. Origin of the Cheltenham waters. 3, 3. Lias clays and marls. 4. Alluvium.

waters, it appears "that their principal constituents are the chloride of sodium (muriate of soda) or sea-salt, and the sulphates of soda and magnesia. Sulphate of lime, oxide of iron, and chloride of magnesium, are present in some wells only, and in much smaller quantities. Besides these ingredients, *iodine* and *bromine* have been detected by Dr. Daubeny, who instituted experiments to ascertain whether these two active principles, which the French chemists had recently discovered in modern marine pro-

* See Sir R. I. Murchison, on the mineral springs of Gloucestershire and Worcestershire. Silurian System, p. 34.

ductions, did not also exist in mineral waters issuing from strata formed in the ancient seas.

As the saline springs of the red marls rise up through the Lias (*Lign.* 121), they undergo certain chemical changes. From the decomposition of the sulphate of iron which takes place, a vast quantity of sulphuric acid must be generated, which reacting on the different bases of magnesia, lime, &c. contained in the strata, forms those sulphates so prevalent in the higher or pyritous beds of the Lias; the oxide of iron being at the same time more or less completely separated. By this means the mineral waters, which are probably mere brine-springs at the greatest depths, acquire additional medicinal qualities as they ascend to the places whence they flow. At the same time it must be borne in mind that fresh water is continually falling from the atmosphere upon the surface of the Lias clays, and percolating through the uppermost strata.*

6. Conglomerates of the Trias.—The conglomerates of this formation are chiefly composed of pebbles and detritus, derived from the destruction of igneous and metamorphic rocks, as slate, quartz-rock, granite, porphyry, &c.; even the fine siliceous sandstones contain a large proportion of debris. It would, therefore, appear that the sea which deposited the saliferous group, was bounded by the rocks of whose ruins it is composed; in like manner as the existence of beaches of flint-pebbles evinces the destruction of former chalk-cliffs.

The rock on which Nottingham Castle is built, is a conglomerate formed of the ruins of the ancient rocks of the neighbouring districts. The rounded pebbles of quartz,

* The origin of the Cheltenham waters was first pointed out by Sir R. I. Murchison, in his elegant volume "On the Geology of the Neighbourhood of Cheltenham," 1834. See the "Silurian System," for a masterly sketch of the Lias and Trias of Worcestershire, Shropshire, &c.

Lydian-stone, granite, jasper, porphyry, slate, &c. seem to have originated from rocks formerly connected with the range of Charnwood Forest. Still nearer the Charnwood hills, the finest sandstone contains fragments of slate. Mr. Bakewell was of opinion that a large proportion of the materials of the Triassic strata was derived from trap and other igneous rocks; and that the red marl was the debris arising from the decomposition of the less indurated volcanic products ; hence, probably, the extreme fertility of the soil.*

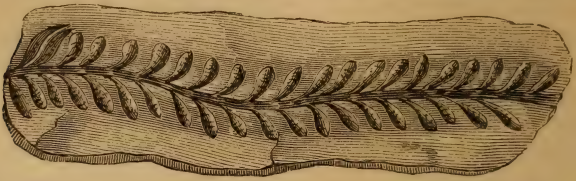
But the most interesting of these conglomerates, or breccias, in England, are those in which eruptions of lava appear to have been thrown into the ocean of the New Red, and to have cemented together the water-worn materials, so as to form a *trap conglomerate ;* such, at least, seems to have been the origin of the amygdaloidal trap, as it is termed, in the vicinity of Exeter.† A few miles to the south of that city, masses of a rock of this kind are interposed between beds of sandstone ; the general appearance of the stone is that of a granular rock, somewhat loosely compacted, of a purplish-brown colour, interspersed with minute portions of calcareous spar, mica, and indurated clay tinged by copper or manganese. It is full of small cells, which are either filled or lined with manganese, calc-spar, or jasper ; a structure termed in geology *amygdaloidal,* or almond-like : the substance of the rock is an earthy felspar.

7. Organic Remains of the Trias.—This formation presents a remarkable contrast with that of the Jurassic, in the paucity of organic remains ; for while the latter teems with marine fossils, the former, throughout immense areas, is almost wholly destitute of any vestiges of animals or vegetables ; a proof that the strata were, for the most part, accumulated under conditions unfavourable for the preservation of organic structures. Several fucoid plants, and

* Introduction to Geology, fifth edition, p. 279.

† Geology of England and Wales, p. 294.

between twenty and thirty species of ferns and coniferæ, have, however, been obtained and determined. Among these are fronds of a plant bearing some resemblance to the



LIGN. 122.—FOSSIL PLANT ALLIED TO THE ADDER'S-TONGUE; FROM THE RED MARL, SULTZ-LES-BAINS.

(Filicites scolopendrioides; one-half the natural size.)

Adder's tongue (*Asplenium scolopendrium*), so common on the banks of our woods and copses; a specimen discovered by M. Voltz exhibits the fructification on the back of the leaf (*Lign.* 122). But the most characteristic plants of the Triassic flora are coniferæ belonging to a genus named *Voltzia*,* which differ from any now living, but closely resemble the Araucaria, or Norfolk Island pine. Fragments of these fossil plants are frequent in the greenish marls near Strasburg: two specimens are figured in *Lign.* 123; *fig.* 2, shows the fructification.† Several species of equisetaceous plants (*Calamites*) abound; one of which, the *Equisetum columnare*, also occurs in the Oolite. The remains of a very peculiar arborescent fern, of a large size, some of the fronds being upwards of two feet in length, have been collected from the same place;‡ and several liliaceous plants.

In the Trias near Chemnitz, in Saxony, silicified stems

* From the late M. Voltz of Strasburg, by whom they were first discovered.

† See Essai d'une Flore du Grès Bigarré; par M. Ad. Brongniart, Ann. Sciences Nat. 1828.

‡ This fossil plant is named *Anomopteris Mougeoti*; Medals of Creation, vol. i. p. 119.—Brit. Mus. Collect.

of arborescent ferns, of great beauty, are met with ; and a few trunks of trees, apparently coniferæ, have been discovered in the Red sandstone, near Coventry.*

A very remarkable fossil has been found in the Triassic sandstone, near Liverpool ; it is a leaf of considerable size,

1 2

LIGN. 123.—CONIFERÆ OF THE TRIAS; FROM SULTZ-LES-BAINS.

Fig. 1. Voltzia longifolia.
— 2. ——— brevifolia; with the fructification.

(Collected by M. Voltz.)

bearing a striking resemblance to the foliage of some of the thick-ribbed cabbages.† I will only add, that as a whole, the flora of the Trias, or Upper New Red, presents a community of

* Medals of Creation, vol. i. p. 128.
† Sir R. I. Murchison's "Silurian System," p. 43.

character by which it is separated alike from the vegetation of the older formations below, and of the Lias above.

8. MOLLUSCA AND CRINOIDEA.—Polypiferous zoophytes and corals, which are so abundant in the Jurassic formation,

LIGN. 124.—THE LILY ENCRINITE, FROM THE MUSCHELKALK, NEAR BRUNSWICK. (*Encrinus moniliformis.*)

are very rare in the Trias. The shells comprise a few species of Trigonia, Posidonomya,* Terebratula, Avicula, Ostrea,

* *Posidonomya minuta* is, I believe, the only British species.

&c., and some peculiar Ammonites.* The Radiaria consist of a few Star-fishes, Cidares, Pentacrinites, and Encrinites. Of the latter, a most beautiful form of this family of Crinoideans is exclusively found in the Muschelkalk.

This is the *Lily Encrinite* (*Lign.* 124), so named from the supposed resemblance of the animal, when in repose, to a closed lily: in the lecture on Zoophytes I shall describe this elegant fossil more particularly: the specimens hitherto obtained are from the neighbourhood of Hanover.

9. Fishes of the Trias.—The bone bed that intervenes between the Lias and Trias (*ante*, p. 529), contains teeth and dorsal rays of numerous small fishes of the genera *Acrodus*, *Ceratodus*, *Gyrolepis*, *Hybodus*, and *Nemacanthus;* similar remains occur, but very rarely, in the sandstones and conglomerates. One of the most striking ichthyological features of the Triassic and Permian deposits, is the prevalence of fishes of the genus *Palæoniscus*, of which several species abound in the marls, sandstones, and limestones, of England, Europe, and North America. These fishes belong to the ganoids with heterocercal tails, and are covered with rhomboidal scales, which in some species are very small, and in others large. In certain localities the small species are sometimes found in groups of more than two hundred individuals on a slab of stone not exceeding two feet square. As only one species of the genus has been identified in the Trias, the Palæonisci are more properly characteristic of the Lower New Red, or Permian system.

10. Reptiles of the Trias.—The Triassic strata not only contain teeth and bones of several remarkable reptiles, but also bear the foot-marks, or imprints of the feet, of many animals, both bipeds and quadrupeds, of whose existence no other traces have, as yet, been discovered.

* Termed *Ceratites*. See Mr. Lyell's "Elements," vol. ii. p. 92.

Although, from the short time that has elapsed since the classification of the New Red system into two distinct formations, the true geological position of some of the strata bearing such imprints is somewhat doubtful, (for some geologists question whether a great part of the New Red of North America may not be referable to the Permian group), it will be convenient to notice the phenomena in question in this place; I will therefore, first, describe the reptilian remains, and afterwards examine the fossil foot-marks.

Bones of several species of Ichthyosauri and Plesiosauri have been found in the Triassic strata of Wirtemberg by Dr. Jaeger of Stutgard. But the most extraordinary reptilian remains, discovered in that country by the same eminent physician, belong to enormous Batrachians, or animals allied to the frog-tribe. The principal fossils consist of portions of the cranium, and jaws with numerous teeth; and an occipital bone, with a double articulating surface,—a proof of its batrachian affinity. Teeth, portions of the skull and jaws, and a few other bones, have since been found in Warwickshire; and by these Professor Owen has ascertained that the animals to which they belonged formed an extinct genus of Batrachians.

11. THE LABYRINTHODON.*—These teeth are of a gently curved conical shape, and present no peculiar external characters; but Professor Owen, having made various sections to examine their intimate structure, found a most extraordinary modification in the arrangement of the dental elements. The teeth of the gigantic reptile of Wirtemberg, (some of which are two inches long), and those from Warwickshire, all possess a remarkable complicated character, produced by the convergence of numerous laby-

* Medals of Creation, vol. ii. p. 784.

rinthine folds of the external layer of cement towards the pulp cavity; and within these inflections, the dentine, or tooth-ivory, is similarly disposed. Transverse sections, therefore, display the most beautiful interfoldings of the two substances; and as the fossils are generally deeply coloured by iron or manganese, they exhibit under a slightly magnifying power, an extremely interesting appearance;* this peculiarity of organization suggested the name assigned to this genus of fossil Batrachians.†

From the structure of the cranium, it appears that the Labyrinthodon, of which there are five species, had sub-terminal nostrils leading to a wide and shallow nasal cavity, separated from the cavity of the mouth by a broad and almost continuous horizontal palatal flooring. It is, therefore, inferred that these reptiles breathed air like the crocodiles, and were probably furnished with well-developed ribs: thus the first representatives of the Batrachians, of which we have any indication, belong to a higher condition of structure than any now known to exist.‡ The gigantic Wirtemberg Batrachian must have borne the same relation in magnitude to the diminutive existing frog-tribe, as the extinct colossal Iguanodon to the recent Monitors and Iguanas.

Claydyodon.—Several detached pointed, trenchant, recurved teeth, the crowns of which are an inch long, and

* The teeth of the recent *Lepidosteus*, or Stony-gar, a fish that inhabits the rivers of America, have a similar structure, but less complicated than in the Labyrinthodon. See "Medals of Creation," vol. ii. p. 651.

† See "Medals of Creation," vol. iv. Pl. VI. fig. 3.

‡ "As in the existing diversified order of Batrachia, one family (*Perrenibranchiata*) represents Fishes:—a second (*Ceciliadæ*), Serpents:—a third genus (*Pipa*), Turtles: and a fourth (*Salamandra*), Lizards:—so would the now lost Labyrinthodons have formed representatives of the highest order, viz. the Crocodilians."—*Prof. Owen, in Brit. Assoc. Rep.* 1841, p. 197.

five lines broad at the base, have been found in the Grinsill sandstone. They closely agree with the teeth of the thecodont reptiles of the Permian; but Professor Owen regards them as generically distinct, and has named the reptile to which they belonged the *Cladyodon.**

12. RHYNCOSAURUS.—The New Red sandstone quarries at Grinsill, in Warwickshire, have also yielded the remains of a very anomalous modification of reptilian organization, combining the lacertian type of skull with edentulous jaws. The general aspect of the cranium resembles that of a bird or turtle; the intermaxillary bones being very long, and curving downward, thus imparting to the fore-part of the head the profile of a parrot. There are no teeth apparent in either jaw, and Professor Owen supposes that this reptile may have had its jaws encased by a bony or horny sheath, as in turtles. Footmarks of a small reptile, with the print of a hind-toe pointing backwards, occur on the surface of some of the slabs of sandstone in these quarries, and are, with much probability, conjectured to have been impressed by the Rhyncosaurus.†

13. DICYNODON.—Although the geological position of the strata whence the specimens were obtained is somewhat uncertain, yet the relation between the reptiles whose remains I am about to describe and that last mentioned, induces me to notice them in this place. The fossils in question were collected by Mr. Bain,‡ in a compact sandstone, supposed to belong to the Triassic system, near Fort Beaufort in South Africa, and were sent, with many other blocks of stone containing bones, to the Geological

* Report on British Fossils, Rep. for 1841, p. 155.

† Cambridge Philosophical Transactions, vol. vii.

‡ See a notice "On the Discovery of the Fossil Remains of Bidental and other Reptiles in South Africa," by A. G. Bain, Esq.—*Geol. Trans.* vol. vii., new series.

Society.* The principal remains hitherto cleared from the rock, belong to reptiles having a narrow cranium, with nostrils divided as in lizards, and not confluent as in turtles, which otherwise the skull in its general appearance much resembles. The orbits are very large; the jaws are edentulous, as in the Rhyncosaurus above described: but the upper jaw possesses a pair of long tusks implanted in sockets, like those of the *Walrus.*† These tusks are of so fine and dense a texture as to be almost equal in hardness to the canine teeth of the hyena; the largest specimens are two inches in diameter. The vertebræ, as in most of the extinct saurians, are sub-biconcave. This marvellous type of reptilian structure is perfectly unique.

The *Acrosaurus*, is another extraordinary fossil reptile from the same locality. It has thirty or forty teeth on the alveolar ridge; and a broad process of the malar bone extending downwards over the side of the lower jaw, as in the Glyptodon (*ante*, p. 171).

14. Ichnolites, or Footsteps on sandstone.—Some years since, the attention of geologists was excited by the discovery of supposed impressions of the footsteps of quadrupeds, on the surface of the New Red sandstone, at Corncockle Muir, in Dumfriesshire.‡ The imprints resemble

* But a few of these specimens have been cleared. It is to be regretted that they should be thus neglected, for they probably contain other new and interesting fossil remains.

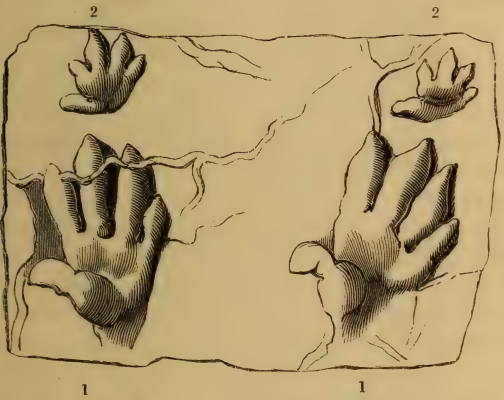
† Hence the name *Dicynodon*, or *bidental*. See Geol. Trans. vol. vii. p. 53, for a report on the reptilian fossils of South Africa, by Professor Owen.

‡ Account of the Marks of Footsteps of Animals found impressed on Sandstone, by the Rev. H. Duncan, D.D. Edinburgh, Trans. Royal Soc. vol. xi. 1828. It is to be regretted that these equivocal markings have received a generic and specific name (*Testudo Duncani, Brit. Fos. Rep.*) The example has already been followed in America, and the over-burthened nomenclature of Palæontology is threatened with another century of hard names, applied to mere imprints on stone, the origin of which is still involved in obscurity.

those made by the paws or pats of land-tortoises. Entire tracks of these imprints, indicating the slow progression of a four-footed animal, appear on some of the slabs. On one block of sandstone there were twenty-four consecutive impressions of feet, forming a regular track, with six distinct repetitions of the marks of each foot, the fore-feet differing from the hind-feet; the appearance of five claws was discernible in each fore-paw. The observations on the ripple-marks on sandstone (*ante*, p. 372) render it unnecessary to explain the preservation of imprints of this nature. Similar appearances have since been observed on the sandstone in the Stourton quarries near Liverpool, and in several places in Germany: but no bones of tortoises have been discovered in these strata.

A discovery of a like nature was made soon afterwards in the New Red sandstone near Hildburghausen, in Saxony. Numerous imprints of the feet of some large quadrupeds, having the fore-paws much smaller than the hinder, were observed on the exposed surfaces of some slabs of rippled sandstone: and recently, similar footsteps have been found in the quarries at Stourton. These imprints are on the face of each successive layer of stone, and on some of the slabs, not only are there foot-prints of various kinds of animals that walked over the stone when it was in the state of soft sand, but also the impressions of rain-drops. Some of the recently exposed surfaces present a blistered or warty appearance, being covered either with little hemispherical eminences, or with depressions; and these, upon an accurate investigation of the phenomenon, prove to have been the effect of rain, which fell while the surface was soft and impressible. On many of the slabs the forms of the rain-drops and of the foot-prints, appear in relief, being casts of the surface upon which the impressions were made; while on the clay, corresponding hollows are apparent (*Lign.* 126.).

Chirotherium.—The foot-prints are of various kinds; some appear to have been produced by small reptiles and crustaceans; but the principal markings are referable to some large quadruped, in which the fore-feet were much smaller than the hinder (*Lign.* 125). From the supposed resemblance of these imprints to the shape of the human hand, the name of *Chirotherium* has been adopted to designate the animals which left these enigmatical "footsteps on the sands of Time." Since the discovery of the bones of



LIGN. 125.—FOOT-MARKS OF AN UNKNOWN ANIMAL ON SANDSTONE; FROM HILDBURGHAUSEN.

Fig. 1. 1. Impressions of the hinder feet of an unknown animal (provisionally named *Chirotherium*). 2. 2. Imprints of the fore feet of the same.

(One-eighth the natural size.)

gigantic Batrachians in the same strata, it has been suggested that the footmarks were produced by some of the large Labyrinthodons; a conjecture highly probable, for the fore and hind feet of many of the frog-tribe are as dissimilar in size as those of the so-called Chirotherium; but till the form of the feet of the extinct batrachians is known, no certain conclusion can be drawn as to the origin of these impressions.*

15. Ornithichnites, or fossil footprints of birds.—In the United States of North America, a group of strata, which from the plants (*Voltziæ*), shells (*Posidonomya Keuperi*), and fishes (*Palæonisci*), appears to belong to the Triassic system, occurs in the valley of the Connecticut river, stretching through the states of Connecticut and

Lign. 126. Foot-mark of a Biped, and impressions of rain-drops; on Sandstone; Massachusetts, (*nat. size*).

Massachusetts; and a band of similar deposits ranges beneath the Palisadoes of the Hudson, to the interior of

* See Dr. Buckland's "Bridgewater Essay" for figures and further details. A fine series of specimens of Chirotherium imprints are in the Brit. Mus. Collect.

Virginia. The materials are red shale and argillaceous sandstone, with detached beds of conglomerate.* It is on the surface of the laminated argillaceous sandstones of this system, and principally in the valley of the Connecticut, that occur those mysterious characters, on which the sagacity and unremitting labours of Professor Hitchcock, have thrown so much light; but at present the nature of the animals by which the foot-prints were made is involved in obscurity, for not a vestige of the skeletons of the bipeds, the lineaments of whose feet are so vividly apparent, have been discovered.†

The origin assigned to these markings was for a long while disputed, but Professor Hitchcock's interpretation is now generally admitted; though the discovery of bones of birds in strata of this epoch is required, before the question can be regarded as determined. The number and variety of these footsteps are so considerable, that Professor Hitchcock considers he has sufficient data to warrant their arrangement in numerous genera and species, belonging to several families of birds.‡ The abundance of foot-prints on the Connecticut sandstones, is explained by supposing the strata to have originated from sediments deposited in a tidal estuary; and that various kinds of birds frequented the low muddy shores, when the tide receded, in pursuit of worms, and other

* Professor Henry Rogers' Address at the Meeting of the Association of American Geologists, May, 1844,

† I must refer the reader to the original work of Professor Hitchcock, "A Report on the Geology of Massachusetts;" to Dr. Buckland's "Bridgewater Essay;" to the "American Journal of Science," for many interesting papers, by Dr. Deane, (who first drew Professor Hitchcock's attention to the subject,) and other American naturalists; and to the "Medals of Creation," vol. iii. p. 808.

‡ See "Final Report on the Geology of Massachusetts," p. 477; and the same accomplished author's admirable little volume, "Elementary Geology," p. 155.

prey; and that their footsteps were covered with a thin layer of silt at each reflux of the waves.

The following remarks of Dr. Deane will convey an idea of the colossal proportions of some of these imprints :—"I have in my possession consecutive impressions of tridactyle feet, which measure eighteen inches in length, by fourteen in breadth, between the extremities of the lateral toes. Each footstep will hold half a gallon of water, and the stride is four feet. The original bird must have been four or five times larger than the African Ostrich, and therefore could not have weighed less than 600 pounds. Every step the creature took sank deep, and the sub-strata bent beneath the enormous load. If an ox walk over stiffened clay, he would not sink so deeply as did this tremendous bird."*

Mr. Lyell mentions having seen on the banks of the Connecticut river, (at Smith's Ferry, near Northampton, eleven miles from Springfield,) a space several yards square, where the entire surface of the shale was irregular and jagged, owing to the number of footsteps, not one of which could be traced distinctly, as when a flock of sheep have passed over a muddy marl; but, on withdrawing from this area, the confusion gradually ceased, and the tracks became distinct.†

Some fine slabs of the sandstone, covered with several tracks of bipeds of various sizes, collected by Dr. Deane, are deposited in the British Museum. A representation of one of the small imprints of the natural size, with the surface of the stone marked with hemispherical pits produced by a shower of rain, is given in *Lign.* 126.‡

The enormous magnitude of some of the foot-prints was formerly deemed an insuperable objection to the interpretation of these obscure vestiges adopted by the American

* Boston Journal of Nat. Hist. vol. v. No. 2.

† Travels in America, p. 254.

‡ Consult "Medals," vol. ii. pp. 810—816, for particulars.

naturalists ; but the discovery of the bones of tridactyle birds (*Moa*, see *ante*, p. 129), in the alluvial deposits of New Zealand, some of which indicate a size equal to that of the most colossal of the fossil imprints, has removed that objection, and shown that in comparatively modern times, the earth was trod by birds as gigantic as the bipeds, that strode along the sea-shores of the Triassic ocean.*

I must not, however, dwell longer on this inviting subject, and will only add, that while offering my humble tribute of admiration to the sagacity and patience with which the subject has been investigated by Professor Hitchcock and others, and fully admitting the close resemblance of the bipedal fossil foot-prints to those of birds, I consider the following caution of Professor Owen to be deserving of the most serious attention:—"Foot-prints alone, like those termed 'Ornithichnites,' are insufficient to support the inference of the progression of the highly developed organization of birds of flight, by the creatures which have left them. The Rhyncosaur, and the biped Pterodactyles, already warn us how nearly the ornithic type may be approached, without the essential characters of the Saurian being lost; and by the Chirotherian Ichnolites, we learn how closely an animal, in all probability a Batrachian, may resemble a pedimanous mammal in the form of its foot-prints."†

16. The Permian (*Magnesian Limestone*) Formation.—The group of strata thus designated was formerly termed

* The close resemblance of many of the American foot-marks to those made by recent birds is most striking. Mr. Lyell, in his charming volumes, "Travels in North America," has placed this correspondence, I might almost say identity, in a strong point of view, by giving figures of recent foot-marks of the Sandpiper, on hardened red mud, from the Bay of Fundy; these specimens are now in the British Museum for comparison with the fossil imprints.—See "Travels in North America," vol. ii. pl. vii.

† Brit. Assoc. Rep. 1841, p. 203.

the Lower New Red, or Magnesian limestone formation; it comprises the Zechstein and Rothliegende of the Germans, and all the deposits that intervene between the lowermost bed of the Trias and the Carboniferous system. Like the upper series, it consists of marls, clays, and conglomerates, more or less coloured by hydrates and oxides of iron, pyritous shales, gypsum, &c. It comprises strata of great extent and thickness, of limestone containing a large proportion of magnesia, and of a crystalline calcareo-magnesian stone, termed *Dolomite.** I have already mentioned that this system is paleontologically characterized by a peculiar type of organic remains, and by the absence of every species of fossil that occurs in the newer, or overlying formations; hence the Permian is ranked as the last, or uppermost, of the palæozoic class. (See Synopsis, p. 203.)†

In Somersetshire, and the adjacent country around Bristol, beds of conglomerate, formed of the debris of older rocks, held together by a dolomitic cement, are spread unconformably over the carboniferous strata, filling up the irregularities and hollows of the surface of the mountain limestone, &c. occasioned by the dislocations and fractures which those rocks had sustained by disturbing forces, before the deposition of the Permian deposits. This

* The granular crystalline magnesian limestone is termed *Dolomite,* from M. Dolomieu, who first pointed out its mineralogical character. This rock has the same external aspect as granular limestone; but, instead of being a pure carbonate of lime, contains from 45 to 60 per cent. of carbonate of magnesia.

† The arrangement adopted in the text is that now generally received by British geologists; at the same time it must be stated, that very able observers limit the term "*palæozoic*" to the formations below the carboniferous system, and rank the Permian with the *mesozoic*, or middle secondary strata. See a Paper on the "Termination of the Palæozoic Period," by Dr. Dale Owen, "American Journal of Science," for May, 1847, vol. iii. New Series, p. 365.

conglomerate is made up in great part of pebbles, and fragments of mountain limestone, millstone grit, coal-shale, and other detritus of the strata on which it reposes; and contains fractured and water-worn bones of Saurians, teeth of fishes, &c. It is well displayed, overlying the coal strata and mountain limestone, near Clifton in the valley of the Avon, and at Portishead, and other places in the vicinity.*

In the central part of England, and extending from the neighbourhood of Nottingham to the south-eastern extremity of Northumberland, red marls and sandstones form the lowermost strata of the Permian, and are regarded as the equivalents of the *Red-lyer* or *Rothliegendes* of Germany; a term applied to a group of red sandstones and conglomerates, accompanied with porphyry, and basaltic and amygdaloidal trap, that constitutes the base of the Permian of the Continent. Upon these lower red sandstones are yellow and reddish magnesian limestones, upwards of 300 feet in total thickness, corresponding with the *Zechstein* of Germany.

17. Magnesian Limestone or Dolomite.—The magnesian limestone of England is regularly stratified, and, when recently exposed, has a granular or saccharine structure, with a glimmering lustre; the colour is generally either a pale fawn, salmon, or yellow, from hydrate of iron; or red, from oxide of iron. The hard varieties yield the best building stone in England.† In many places the limestone occurs in large concretional and botryoidal masses; the concretions varying from the size of small peas

* The lower part of the strata marked *Trias* in the section of the Mendips (*Lign.*118, p. 522), more properly belongs to this group; the dolomitic conglomerate very generally forms the immediate covering of the older deposits in this part of England.

† The New Houses of Parliament at Westminster are being constructed externally of magnesian limestone, from quarries at North Anstone in Yorkshire, and near Worksop in Nottinghamshire.

to that of a large cannon-ball; and these are often grouped together like bunches of grapes, or masses of chain-shot. On the coast of Durham, the whole cliff is made up of large concretional clusters, resembling piles of cannon-balls. This phenomenon is best seen near Sunderland, and along the shore near Marsden and Black rocks; where it is associated with other curious and interesting modifications of concretional action.* These masses offer a beautiful illustration of spheroidal structure, superinduced on stratified detritus *after its deposition;* for the sedimentary laminæ pass through the globular concretions uninterruptedly. The limestone is commonly traversed by veins and strings of carbonate of lime, and occasionally contains hollow spheroids of calcareous spar, and crystals of sulphate of strontian and barytes. Galena, or sulphuret of lead, sulphuret of zinc, calamine, and carbonate of copper, also occur; and some veins of galena in the Mendip hills have yielded profitable returns.†

18. Permian of Germany and Russia.—In Thuringia, in Saxony, the magnesian limestone (*Zechstein*) is largely developed, and associated with beds of dark bituminous shales and marls highly charged with copper pyrites, which are termed *Kupfer-schiefer*. These shales have long excited the attention of naturalists, from the number and variety of the fossil fishes they contain, and the peculiar mineralized condition in which these relics occur; specimens from Eisleben in Mansfeld, a celebrated produc-

* See an admirable memoir, "On the Geological relation and internal structure of the Magnesian Limestone," by the Rev. Adam Sedgwick, Geol. Trans. vol. ii. p. 50. The dolomitic conglomerates around Bristol are ably described by Dr. Buckland and Mr. Conybeare, *Ibid.* vol. i. A valuable paper by Messrs. Murchison and Strickland, on the "Upper New Red of Gloucestershire," &c. will be found, *Ibid.* vol. v. p. 331.

† Geology of England and Wales, p. 304.

tive locality of these ichthyolites, are to be found in almost every museum in Europe. These fishes, which principally belong to the genera *Palæoniscus* and *Platysomus*,* are generally in a contorted state, apparently the effect of violent convulsions attendant on their sudden destruction. They are splendidly invested with copper pyrites, and their scales often have the appearance of burnished gold. The bodies of the vertebræ of the spinal column are almost always wanting.† The appearance of a violent death presented by these Ichthyolites, M. Agassiz considers as entirely deceptive: and states that the bent and twisted condition of the body is solely attributable to muscular contractions during decomposition after life was extinct.‡

In Russia, the researches of Sir R. Murchison have shown that the Permian system in European Russia, consists of strata identical with the lower group of New Red of England and Germany, and reposes on the carboniferous deposits; it extends over an area 4,000 miles in circumference; a space equal to twice the surface of the kingdom of France.

In North America, as we have already hinted, it seems probable that the lower deposits of the New Red may be found to belong to the Permian group.

19. Fossils of the Permian System.—The fauna and flora of this formation are invested with peculiar interest, because they present us with the last term of that ancient type of organic life, which prevailed from the earliest periods of which we have obtained any evidence of the presence of living things in the waters or upon the surface of our planet. For the two grand revolutions in the organic world, as demonstrated by fossil remains, are unquestionably those which separated the palæozoic ages from the secondary, and the latter from the tertiary. There are no less than 166 species of fossil plants and animals

* Medals, vol. ii. p. 633. † Ibid. p. 634.

‡ Recherches sur les Poissons Fossiles, tome ii. p. 70.

from the Permian deposits which have been accurately determined; of these 148 are unknown in any other formation.

Plants.—The plants are referable to genera common in the coal measures, but very rare or altogether wanting in the formations above the Permian; for example, species of *Lepidodendron*, *Nöggerathia*, *Odontopteris*, &c.; indicating a continuation of vegetable life of the same nature as that which prevailed during the carboniferous era.

20. INVERTEBRATA OF THE PERMIAN.—The *Radiaria*, *Mollusca*, and *Articulata*, are represented by the following genera and species:—

Fifteen species of *Corals*:* *Crinoidea*, so abundant in the Carboniferous strata, are of excessive rarity.

Thirty species of Brachiopodous shells, ten of which are common to the Carboniferous; the other twenty are new.

There are six species of *Productus*, and eight species of *Spirifer*; both these genera appear for the last time.

Of *Orthis*, one of the earliest forms of the family, and very characteristic of the Silurian, three species.

Terebratulæ with oblique and vertical septa, bearing a close analogy to the *Pentameri* of the Devonian and Silurian: nine species.

Species of *Modiola* and *Axinus*; and of *Avicula*, eight species. *Posidonomya*, a few species.

Gasteropoda, fifteen species, of which twelve are new.

Chiton, a few species have been found near Sunderland.

Cephalopoda scarcely a vestige: only doubtful specimens of *Nautilus*, or *Cyrtoceras*.

Of the *Trilobites*, which in the Carboniferous system are reduced to some few small species, there are no traces whatever. But there is a large and peculiar species of *Limulus* (*L. oculatus*); and this genus which first appears in the coal system has continued to the present time.†

21. FISHES OF THE PERMIAN.—The fishes of this system comprise between forty and fifty species, belonging to

* The *Retepora flustracea* is a very abundant and characteristic coral of the Sunderland magnesian limestone.

† This notice is principally taken from the Tabular list of the animal remains of the Permian System, in Sir R. Murchison's "Geology of Russia," vol. i. p. 221.

sixteen or seventeen genera; and with, but one exception, (the *Palæoniscus Freislebeni* of the upper coal-measures), are peculiar. All the ichthyolites of this group possess that remarkable modification of the tail, which we have already mentioned as having been of excessive rarity in the fishes of the secondary and tertiary seas, as well as in those that inhabit the existing ocean; in which the Sharks and Sturgeons are almost the only representatives of this palæozoic type. The caudal fin is universally heterocercal, *i. e.* the vertebral column is prolonged at its extremity into the upper lobe of the tail.*

Ganoid fishes of the genera *Palæoniscus*,† and *Platysomus; Cestracions*,‡ *Hybodonts;* and a remarkable form of those extraordinary fishes, the Chimeroids, named *Ceratodus;*§ constitute the principal features of the Permian ichthyic fauna. Species of the two first genera have been found in abundance in various localities in England, on the Continent, and in North America, and are figured and described by various authors.‖ Their remains are the only relics of vertebrated animals hitherto discovered in the sandstones impressed with the footsteps previously examined.¶

* See *Lignograph* of the restored figure of the Amblypterus of the Carboniferous system; in which *a* marks the prolongation of the vertebral column into the upper lobe of the caudal fin: this fish is a good illustration of the *heterocercal* type; and the *Lepidotus* of the Wealden, (*Lign.* 99, p. 408,) affords an example of the *homocercal*, or equal-lobed tail.

† Medals, vol. ii. p. 633.

‡ Medals, vol. ii. p. 613.

§ Medals, vol. ii. p. 618. The teeth or dental plates of several species of Ceratodus, occur in the New Red of Germany, especially at Hohneck near Ludwigsburg.

‖ Professor Sedgwick's memoir is accompanied by numerous figures of Palæonisci.—*Geol. Trans.* vol. iii. pl. 12.

¶ The characters of the Ichthyology of the New Red are thus expressed by M. Agassiz, ‘Les formations triassiques et le Zechstein

22. REPTILES OF THE PERMIAN.—The earliest certain indications of the existence of reptiles on our globe, have been obtained from the deposits of the Permian system ; for no teeth or bones of any animals of a higher order than fishes, have been discovered in any of the more ancient formations. Impressions of the footsteps of quadrupeds have however recently been observed on limestones of the carboniferous epoch in North America ; and during the present year, the skeleton of a saurian, four feet long, is said to have been found in strata of the same age in Germany.* It is therefore probable, that we shall ere long, obtain proofs that cold-blooded quadrupeds were coeval with the luxuriant flora of the coal.

In the Zechstein of Thuringia, and in the Dolomitic conglomerate of Somersetshire, the remains of several genera of large thecodont† lizards have been discovered.

Thecodontosaurus and *Palæosaurus*.—These British fossils were obtained from Redland, near Bristol, and are preserved in the museum of that city ; they consist of jaws, teeth, vertebræ, and bones of the extremities, referable to two genera of saurians, named as above by Dr. Riley and

forment un groupe des plus remarquables par sa faune ichthyologique, Des *Chimérides* de forme étrange, les *Ceratodus,* et les *Némacanthes* sont nombreux : des *Cestraciontes* appartenant aux genres *Dictæa, Janassa, Acrodus,* et *Strophodus,* et des *Hybodontes,* sont à cette époque les représentans de l'ordre des Placoïdes. Parmi les Ganoides on distingue des Lépidoïdes des genres Platysomus, Gyrolepis, et Palæoniscus ; des Sauroïdes des genres Acrolepis, Pygopterus, et Saurichthys, des Célacanthes et des Pycnodontes, parmi lesquels les genres Placodus et Colobodus sont surtout caractéristiques pour le Muschelkalk."—*Recherches sur les Poissons Fossiles,* tome i. p. xxix.

* Mr. Lyell has shown me a slab of stone from the middle of the coal strata of Pennsylvania, on which there are decided footprints of a quadruped, apparently of the Batrachian order. See "American Journal of Science," vol. ii. new series, p. 25. Footmarks of this kind were first discovered and described by Dr. A. T. King of Greensburg ; see *Op. cit.* vol. i. p. 268.

† *Thecodont ;* i. e. having the teeth implanted in distinct sockets, like the crocodile.

Mr. Stutchbury, by whom they were first made known.* The teeth are pointed, compressed laterally, trenchant, and finely serrated on the edges. These reptiles, in their thecodont type of dentition, biconcave vertebræ, double-headed ribs, and proportionate size of the bones of the extremities, are nearly related to the Teleosaurus of the Oolite (*ante*, p. 531); but combine a lacertian form of tooth, and structure of the pectoral arch, with these crocodilian characters: and the bodies of the vertebræ have a series of ventricose excavations for the spinal chord, instead of a cylindrical canal.† The reptile found in the Zechstein, and termed the *Thuringian* monitor (*Protorosaurus*), appears to be related to the thecodont saurians of Bristol. The spinous processes of the dorsal vertebræ are described as remarkably high, and the caudal vertebræ are characterized by double diverging spinous processes.‡

Rhopalodon.—A fragment of a jaw with teeth, and a few detached teeth, of a thecodont reptile, apparently related to the Bristol saurians, are, I believe, the only reptilian remains hitherto obtained from the Permian deposits of Russia. They are figured and described by M. Fischer under the name of Rhopalodon.§

From what has been advanced respecting the fossils hitherto found in the Permian formation, it appears, that while specifically the organic remains are distinct from those of the contiguous upper and lower systems, yet they present a closer relation to the ancient types, than to the forms which predominate in the upper and newer deposits.

23. Reptiles.—As with the Permian deposits, the multitude of reptilian forms with which we have been surrounded in our progress through the faunas of the

* Geological Transactions, vol. v.

† Ibid. vol. v. pl. xxix. figs. 6, 7. ‡ Professor Owen.

§ Sur le Rhopalodon, genre de Saurien Fossile, du Versant Occidental de l'Oural; par G. Fischer de Waldheim. Moscou, 1841.

secondary epochs disappears, I will here offer a few general observations on this class of animals, that the unscientific inquirer may be enabled to comprehend the inferences that arise from the facts that have been submitted to his notice.*

All animals possess organs by which a certain change is effected in the circulating fluid, to refit it for the purposes of nutrition. Mammalia, birds, and reptiles, are furnished with an apparatus of cellular tissue, termed lungs, by which a large surface of the blood is brought in contact with the air ; in aquatic vertebrata this apparatus is the gills, which are organs fringed with innumerable processes, supplied by myriads of vessels, disposed like net-work, by which the blood is exposed to the action of aerated water, oxygen absorbed, and vitality maintained. In Reptiles, the respiratory organs are less developed than in any of the other vertebrated animals, but they all possess lungs, and are capable of breathing air : and some have gills, and perform aquatic respiration. The heart, which is generally three-chambered, is so disposed, that at each contraction only a portion of the volume of blood is sent to the lungs ; hence the action of oxygen on the circulating fluid is in a less degree than in any of the mammalia, birds, or fishes. As animal heat, the susceptibility of the muscles to nervous influence, and even the nature of the skin, are dependent on respiration, the temperature of Reptiles is low, and their muscular powers are, on the whole, very inferior to those of Birds or Mammalia ; requiring no integuments, as hair, wool, or feathers, to preserve their temperature, they are merely covered with scales, or have a naked skin. As they can suspend respiration without arresting the course of the

* See my "Medals of Creation," vol. ii. chap. xvii. ; where the subject is so fully considered that a brief notice only is here necessary. For a comprehensive and philosophical view of this department of Palæontology, the English reader should study the memoirs of Prof. Owen, in Brit. Association Reports, 1840, 1841.

blood, they dive with facility, and remain under water for a long period without inconvenience. Some are viviparous, others are oviparous, laying their eggs, which they never hatch, on the sands or banks. They present great diversity of form ; some are extremely elegant, others grotesque and hideous, and many have dermal processes of the most fantastic shapes. Their habits are exceedingly variable ; some are agile, others torpid ; all hibernate, or rather relapse periodically into a state of dormancy, whether produced by cold, drought, or excessive moisture. Their peculiar structure enables them to endure long abstinence, to an extent impossible to other races of animals. Their seasonal habits, or, in other words, alternate periods of activity and repose, are in accordance with the sudden evolutions of the seasons ; they are dormant when nature does not need their agency, and rouse into activity when required to repress the redundancy of those vegetables or animals which constitute their food ; a property strikingly manifest in the species of hot climates ; thus exhibiting an admirable adaptation to the peculiar conditions of existence which they are destined to fulfil. Some are herbivorous, others carnivorous, and many prey on insects ; their powers of progression are as various ; some orders, though destitute of fins, wings, or feet, bound along the ground with great agility ;* others walk or swim ; while a few are capable of flight.†

24. Turtles, or Chelonian Reptiles.—In Turtles the want of active faculties is compensated by their passive means of resistance. They have no weapons of offence, but are enclosed in a panoply of armour formed by the expansion of the ribs above, and by the bones of the chest beneath. The carapace, or buckler, constituting the shell that spreads over the back of the turtle, is composed of the ribs, which, instead of being separated by intervals, as in other animals,

* The Serpents. † The *Draco volans,* or Flying Dragon.

are spread out and united together. Thus in the delicate and agile form of the Serpent, and in the heavy and torpid mass of the Turtle, the same general principle of structure prevails, and by a simple modification, the skeleton is adapted for beings of very dissimilar forms and habits. The *Testudinata*, or turtles, like the other large reptiles, are essentially confined to torrid and temperate regions. The fresh-water species are capable of bearing a higher latitude than the terrestrial: upon the whole the utmost range of this order appears to be from 54° N. lat. to about 40° S. lat.* The fluviatile species, or *Emydes*, are carnivorous, feeding on frogs and small animals; those of the genus *Trionyx* (*three claws*) are African or Asiatic; with the exception of the *Trionyx ferox*, which inhabits the hot regions of America. They live upon food which is found at the bottoms of rivers; in the stomachs of several procured from the Ganges, by Col. Sykes, were large quantities of mussels, the shells of which were broken into small angular fragments. I have fossil bones of a Trionyx (*T. Bakewelli*) from Tilgate Forest, imbedded in a mass of mussel shells; a collocation which might be expected in a fluviatile deposit. The form of the ribs and other parts of the skeleton, differs in the land, river, and marine Turtles, so that the fossil bones can, for the most part, be readily referred to the respective groups.

Fossil Turtles.—The earliest indications of the existence of reptiles on the surface of our planet were supposed to be those of Chelonians; the imprints of the feet or pats apparently of a land tortoise, occurring on slabs of Triassic sandstone in Dumfriesshire (*ante*, p. 555); but recent discoveries afford glimpses of a more ancient race of batrachians, and of lizards, even as low down in the geological scale

* On the Testudinata, by Thomas Bell, Esq. 1 vol. folio; one of the most splendid works on Natural History that has appeared in this country.

as the Carboniferous system. Throughout the Oolitic, Wealden, and Cretaceous epochs, terrestrial ?, marine, and fresh-water Chelonians abounded. From the most ancient Tertiary to the present time, the three groups of this order of reptiles have flourished. Their remains are associated with those of the Sivatherium, &c. in the Sub-Himalayahs, of the Mastodons in the Burmese empire, of Palæotheria in the Paris and London basins, and with fruits and tropical plants in the Isle of Sheppey: their bones and eggs are daily imbedded in the recent conglomerates of the Isle of Ascension. The remains of living species of Indian land tortoises are collocated with the bones of the most ancient extinct eocene mammalia in the Sewalik hills.*

25. Crocodiles.—This family of loricated or mailed saurian reptiles, contains the only living types that at all approach in magnitude the colossal forms of the secondary epochs. The Egyptian Alligator, as is well known, attains a large size; and the long and slender-beaked crocodilian reptile of India, the Gavial of the Ganges, sometimes reaches a length of nearly thirty feet. The peculiar character of the teeth of these animals, and their mode of increase and renovation, have already been pointed out (*ante*, p. 414). The vertebræ, or bones of the back, are concavo-convex; *i. e.* united to each other by a ball and socket joint, the convexity being behind. Some of the fossil crocodiles of the tertiary also have this structure of the spinal column; but in every crocodilian of the secondary formations, the articulating surfaces of the vertebræ are either flat or concave; except in one genus (*Streptospondylus*, *ante*, p. 414†), in which the vertebræ are convexo-concave, *i. e.* the convexity is directed forwards; a position the reverse of the ordinary type.‡ Reptiles of the crocodilian order, but belonging to several extinct genera, swarmed throughout the

* Dr. Falconer and Major Cautley. † Medals, p. 725. ‡ Ibid. p. 718.

whole of the secondary and earlier tertiary epochs. As the living crocodilians frequent fresh water, the remains of animals of this type indicate the existence of countries watered by streams and rivers, or abounding in lakes : but the modification of the spinal column, so prevalent in the ancient forms, may, perhaps, be referable to a marine, rather than to a terrestrial condition, in some of these extinct saurians.

26. Enalio-saurians, or marine Lizards.*—*Ichthyosaurus* (*Fish-like Lizard*).—In the Lias of the west of England, teeth, vertebræ, and other parts of the skeletons of reptiles, which were supposed to be related to the Crocodiles, had for many years excited attention ; but until 1814, when a considerable collection, from Dorsetshire, formed by Mary Anning, was sold in London, no accurate investigation of these interesting relics had been attempted.† Subsequently a great number of skeletons have been found, numerous memoirs published, and the form and structure of the originals thoroughly investigated. Many beautiful specimens are figured and described in the splendid work of Mr. Hawkins, whose unrivalled collection of these remains is now deposited in the British Museum.‡ The bones of reptiles so abundant in the Lias are chiefly referable to two genera ; the one called *Ichthyosaurus* (by Mr. König), to denote its relation to fishes and reptiles ; the other, *Plesiosaurus* (so named by Mr. Conybeare), to indicate its nearer approach to the Lizards, or Saurians, than the animals of the other genus.

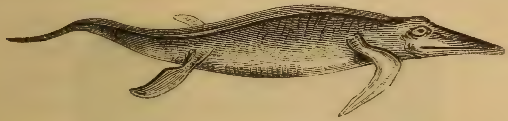
The Ichthyosaurus had the beak of a porpoise, the teeth of a crocodile, the head and sternum of a lizard, the paddles of a cetacean, and the vertebræ of a fish. This restoration (*Lign.* 127) shows its general configuration, as demonstra-

* Medals, p. 708.

† See No. I. of the "London Geological and Palæontological Journal," for an account of the sale of this collection.

‡ Memoirs of Ichthyosauri and Plesiosauri; by Thomas Hawkins, Esq. F.G.S. Folio, with 28 Plates.

ble from the skeleton: but, from the peculiarity of the terminal vertebræ of the tail, Prof. Owen concludes that the original had a strong vertical caudal fin.* There are many species, some of which are of a magnitude equal to that of young whales. The teeth are conical, sharp, and striated, resembling those of crocodiles in the power of reproduction, but differing in the number, situation, and



LIGN. 127.—RESTORED FIGURE OF THE ICHTHYOSAURUS.
(*From Mr. Hawkins.*)

mode of regeneration; one species has 110 in the upper, and 100 in the lower jaw; they are arranged in a deep furrow or groove, not in sockets, and were retained only by the integuments. The orbit is very large, and the sclerotic, or outer coat of the eye, is made up of thin bony plates, arranged round the central opening or pupil, as in the owl and other birds; a mechanism by which the power of the eye is materially increased, and vision adapted to near or remote objects at will. The bones forming the sternum, or chest, which protect the organs of respiration, are strong and largely developed, and the sternal arch offers a remarkable correspondence with that of the Ornithorhyncus, of Australia.

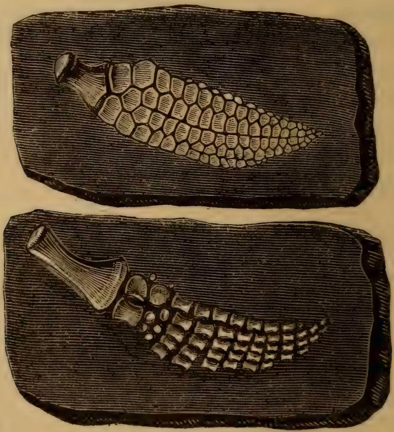
Like turtles, the Ichthyosaurus had four paddles, composed of numerous bones enveloped in one fold of integument, so as to form an entire fin, as in the cetacea;† the fore-paddles

* Medals, p. 712.

† The soft integuments of the paddle are occasionally preserved: See the figure of a beautiful example from Barrow-on-Loar, "Medals of Creation," p. 713.

are large, and in some species consist of one hundred bones ; the hinder pats are smaller, and contain but thirty or forty (*Lign.* 128). The internal structure of these instruments therefore resembles that of the paws of turtles ; and (as is even the case in the fin of the Porpoise) the same elements of an arm are found as in the mammalia, viz. a *humerus*, *radius*, *ulna*, and *phalanges*. The nostrils, which in Croco-

1.



2.

LIGN. 128.—PADDLES OF THE ICHTHYOSAURUS AND PLESIOSAURUS, IN LIAS SHALE, FROM LYME REGIS.

Fig. 1. Left fore-paddle of the Ichthyosaurus.
Fig. 2. Left fore-paddle of the Plesiosaurus.

(*One eighth the natural size.*)

diles are situated at the extremity of the beak or muzzle, are placed, as in the cetacea, beneath the orbits. The vertebræ are hour-glass shaped, like those of the sharks and other fishes ; the spinal column, therefore, admitted of the utmost freedom of motion ; while in the neck, the vertebræ connecting the head to the spine column are anchylosed, and have supplementary bones to increase the strength, and diminish motion.* The general figure of the Ichthyosaurus must have been that of a Grampus or Porpoise, with four large paddles. The teeth prove it to have been carnivorous; the paddles, that it was aquatic; the scales, bones, and other remains of marine fishes, constantly found in the abdominal cavities of the skeletons, and in the coprolites,† that it was an inhabitant of the sea. Its skin appears to have been naked, or at least destitute of scales.‡

27. THE PLESIOSAURUS.§—The discovery of a remarkable specimen, by Miss Anning, enabled Mr. Conybeare at once to establish the characters of that extraordinary extinct

LIGN. 129.—RESTORED FIGURE OF THE PLESIOSAURUS.
(*From Mr. Hawkins.*)

marine reptile, the Plesiosaurus, which differs from the Ichthyosaurus in the extreme smallness of the head, enor-

* Memoir on a Peculiarity of Structure in the Neck of the Ichthyosaurus, by Sir P. M. de Grey Egerton, Bart.

† The *Coprolites*, or fossil excrements of Ichthyosauri (the true nature of which was first ascertained by the sagacity of the Dean of Westminster) are found in profusion in the clays and marlstones of the Lias; often occupying the abdominal cavity of the skeleton (see Dr. Buckland's Bridg. Essay, p. 190); and the state of preservation of these *bezoar-stones*, as they are commonly called, is such, as to show not only the nature of the food of these reptiles, but also the dimensions, form, and structure of the stomach and intestinal canal. The coprolites of the fishes of the chalk often afford like indications. See "Medals of Creation," p. 656.

‡ The *Epidermis*, or scarf-skin, and the *Corium*, or true skin, occur in a fossil state.—Dr. Buckland's Bridgewater Essay, Plate 10, fig. A. 1, 2, 3, 4. Ibid. Pl. 15, contains figures of coprolites.

§ Medals of Creation, p. 714.

mous length of the neck, and other osteological peculiarities.* The neck, which in most animals is composed of five vertebræ, and in the extreme recent example, the Swan, does not exceed twenty-four, consists of from twenty to forty; and its length is equal to that of the entire body and tail. This reptile combines in its structure the head of a lizard, with teeth implanted in sockets like the crocodile; a neck resembling the body of a serpent; a trunk and tail of the proportions of those of a quadruped; with paddles like the turtle. The vertebræ are longer and less concave than in the Ichthyosaurus, and the ribs, being connected by transverse abdominal processes, present a close analogy to those of the Chameleon.

The collection of Mr. Hawkins, now in the British Museum, contains a skeleton eleven feet long, and so nearly perfect, that the entire form of the original creature may be completely restored. Mr. Conybeare compares the Plesiosaurus to a turtle stripped of its shell, and thinks it probable, from its long neck presenting considerable impediment to rapid progress in the water, that it frequented the coast, and lurked among the weeds in shallow water. As it is evident that it must have required frequent respiration, it probably swam on or near the surface, and darted down upon the small fishes on which it preyed.

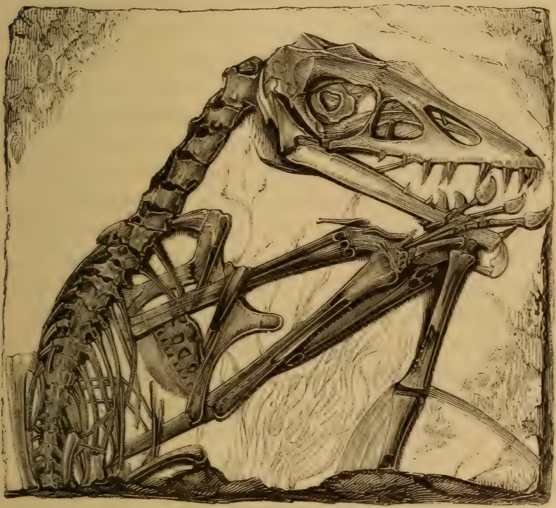
Ichthyosauri and Plesiosauri have been found throughout the secondary strata, from the Lias to the Chalk inclusive; Lyme Regis is the most celebrated locality in England, but the remains of numerous species of both genera have been discovered in many places in this country, and on the Continent, in the Oolite and Lias. The British species of the Enalio-sauri known and described by Professor Owen, amount to ten or twelve of the Ichthyosaurus, and nearly twenty of the Plesiosaurus.† Their remains have been

* In the sternum of the Plesiosaurus the *coracoid* bones have their greatest development.

† British Assoc. Reports for 1839, p. 126.

found in all the deposits, from the Lias to the Chalk inclusive; with the exception of the Wealden, in which no traces of *Ichthyosauri* have been discovered.

28. PTERODACTYLES, OR FLYING REPTILES.*—In this rapid sketch, it will not be necessary to dwell on the first appearance, and subsequent great development of the Lacer-



LIGN. 130.—SKELETON OF A FLYING REPTILE; FROM SOLENHOFEN.

(*Pterodactylus crassirostris, Goldfuss. One-third the natural size.*)

tian tribes, through the periods embraced in this retrospective view, as we have already noticed at considerable length the principal extinct saurians whose remains have been disinterred from the secondary rocks. I pass, therefore, to the

* Pterodactyles, *i.e. Wing-fingered.*—See "Medals of Creation," p. 762.

Pterodactyles, or Flying-lizards of the ancient world, which, unquestionably, present the most extraordinary modification of reptilian organization which the researches of the palæontologist have brought to light. With a head and length of neck resembling those of a bird, the wings of a bat, and the body and tail of an ordinary mammalian, these creatures present an anomaly of structure as unlike their fossil contemporaries, as is the duck-billed Platypus, or Ornithorhyncus of Australia, to existing animals. The skull is small, with very long beaks, which are furnished with upwards of sixty sharp-pointed teeth; the size of the orbit denotes a large eye, and it is therefore probable that these creatures, like other Insectivora, were nocturnal. The forefinger is immensely elongated for the support of a membraneous expansion, as in the Bat; impressions of this membrane are seen in some specimens (*Lign.* 130).* The fingers terminate in long hooks, like the curved claws of the Bat. The size and form of the foot, leg, and thigh, show that the Pterodactyles were capable of perching on trees, and of standing firmly on the ground, where, with their wings folded, they might walk or hop like a bird.†

Sixteen species of these extraordinary creatures have been discovered, and these vary in size from that of a Snipe to a Cormorant. Of these, twelve have been found in the lithographic stone at Solenhofen, where the bones of Pterodactyles are associated with the remains of Dragon-flies;‡ in the Stonesfield Slate they are collocated with the *elytra*,

* The wing of the bat is not merely an instrument for flight, but its structure is so exquisite, and the web so abundantly furnished with nerves, that the organ seems to possess a peculiar sensation, by which the creature, although moving with the utmost rapidity, is enabled to avoid objects in its flight.

† See Dr. Buckland's Bridgewater Essay. Mr. Martin has introduced a restored figure of a Pterodactyle in the foreground of the Frontispiece of Vol. I. of this work.

‡ Goldfuss.

or wing-cases, of beetles; in the Lias, the remains of a species of the size of a Raven, were discovered by Miss Anning.*

Numerous thin delicate bones, evidently belonging to Pterodactyles, have been found in the Wealden, and prove that some species of these extraordinary creatures inhabited the country of the Iguanodon. In the Chalk of Kent, the maxillary bones, with teeth in both jaws, portions of a coracoid bone, several digital bones, and part of the arm-bone, of a large Pterodactyle, have been obtained by Mr. Bowerbank. From a comparison of these relics with the specimen of *P. crassirostris* (*Lign.* 130), the Kentish species appears to have been much larger, and it is estimated that its expanded wings would be six feet wide; it has, therefore, been named *P. giganteus.*† Among existing reptiles, the diminutive *Draco volans* is the only known species capable of flight.

29. Ophidians (*Serpents*) and Batrachians (*Frog-tribe*).—There are no vestiges in the secondary formations of the Ophidians, or reptiles destitute of feet or any extremities for progressive motion; but in the tertiary, bones of a few species of large serpents, allied to the Boæ and Pythons, have been discovered. These fossils were obtained from the Red Crag, at Kyson, in Suffolk, and from the London Clay of the Isle of Sheppey, and Bracklesham Bay.‡ From the size of the vertebræ, Professor Owen ascertained that some of these serpents must have exceeded twenty feet in length. "Serpents of such dimensions," he observes, "exist in the present day only in warm or tropical regions: and their food is by no means restricted to animals of the cold-blooded classes; living birds and quadrupeds constitute the favourite food of the Pythons and Boæ of similar dimensions, which are exhibited in our menageries."§

* Geological Transactions, vol. iii. page 220. This specimen is now in the British Museum.

† Geol. Journal, vol. ii. pl. 1.

‡ Medals of Creation, p. 780.

§ Geol. Trans. vol. vi. p. 209.

Batrachians.—The reptiles termed Batrachians, (from the Greek name for Frog,) are characterized by the remarkable metamorphoses which they undergo, in the progress of their development from youth to maturity. Their organs of aerial respiration consist of a pair of lungs ; but in their young and aquatic state, they are provided with gills, supported on cartilaginous arches as in fishes. The early existence of colossal reptiles of this order, has already been shown in the Labyrinthodons of the Triassic system (*ante*, p. 550). In the pliocene and miocene tertiary strata, the skeletons, imprints of the footsteps, and even vestiges of the soft parts of several species of Frog, Toad, and Triton, have been found.* In the *papierkohle* of the lignites of the Rhine, several kinds, apparently of existing species, are met with. In the neighbourhood of Bombay, small batracholites have lately been found, in a black shale, apparently of a recent date.†

But the most celebrated fossil of this class of the tertiary deposits, is a gigantic Salamander, three feet in length, obtained more than a century since, from the lacustrine limestone of Œningen, in the same quarry which yielded the fossil Fox previously described (*ante*, p. 263). The first discovered specimen of this fossil batrachian (*Lign.* 131) acquired great celebrity, from an eminent physician of his day, Scheuchzer, having, under some extraordinary delusion, regarded it as a petrified human skeleton, and described it under the name of "*Homo Diluvii Testis*," as being "the moiety, or nearly so, of the skeleton of a man, with the bones and flesh incorporated in the stone, and a relic of that accursed race which was overwhelmed by the Deluge."‡

Cuvier, when at Haarlem, in 1811, examined this specimen, and ascertained it to be the skeleton of an extinct

* The ordinary Newt (*Triton*) is an example of this family.

† Geol. Journal, vol. iii. p. 224.

‡ Philos. Trans. for 1726, vol. xxxiv.

species of aquatic Salamander; he cleared away the stone and exposed the four legs, and the jaws, beset with teeth.* There are some fine remains of the Œningen Salamander in the collection of the British Museum.

Lign. 131.—Fossil Salamander of Œningen.

(*"Homo Diluvii Testis" of Scheuchzer. Four and a half feet in length.*)

30. Review of the age of Reptiles. — From this examination of the organic remains of the Secondary Formations we obtain the following results:—that the seas, lakes, and rivers, during these geological epochs, swarmed with reptiles, fishes, mollusca, crustacea, radiaria, polyparia, and other zoophytes; all of extinct species, and presenting as a whole a greater discrepancy with existing forms than those of the Tertiary; the most remarkable feature being the absence of Cetacea, and the presence of several genera of marine Reptiles.

On the land we find no analogy to the terrestrial inhabitants belonging to the tertiary or present eras: throughout the vast accumulations of the spoils of the ancient Islands and Continents, although the remains of crocodiles, freshwater turtles, insects, and terrestrial plants abound, a few

* An admirable account of this fossil is given in "Ossemens Fossiles," tome v. p. 431.

jaws of very small animals are the sole indications of the existence of Mammalia, and the bones of a species of Wader, the only evidence of the presence of Birds. In vain we seek for the relics of Man, or the remains of works of art—for the skeletons of the Mastodon or the Mammoth —of the Palæotheria, or other mammalia that were their contemporaries; the osseous remains of terrestrial and fluviatile Reptiles alone appear. In the emphatic language of Cuvier, "*Nous remontons à un autre âge du monde—à cet âge où la terre n'était encore parcourue que par des reptiles à sang froid—où la mer abonduit en ammonites, en bélemnites, en térébratules, en encrinites, et où tous ces genres, aujourd'hui d'une rareté prodigieuse, faisaient le fond de sa population.*"*

The earliest indications of air-breathing vertebrate animals are the reptiles, and the supposed imprints of their footsteps, of the Permian system. In the succeeding epoch, the Trias, colossal batrachians appear; and on the sands of that ancient ocean are found the foot-tracks of bipeds which seem to point to a higher class, that of birds, for their origin. In the following periods, embracing the deposition of the Lias, Oolite, Wealden, and Chalk, swarms of reptiles belonging to numerous genera every where prevail; species fitted to live in the air, on the land, in lakes and rivers, and in the seas,—yet not one identical with any existing form. These gradually decline as we approach the close of the secondary, and are succeeded in the tertiary, by as varied modifications of the higher animals,—the mammalia and birds. Thus, the faunas of the vast periods that intervened between the tertiary and palæozoic ages, present the following numerical relations in the three higher classes of the vertebrata:†—

* "Ossemens Fossiles," tome v. p. 10.

† This list of fossil reptiles is merely approximative; the number of genera and species is greater than here given.

MAMMALIA . . .	Two genera of very small land animals (*ante*, p. 510.)
BIRDS	One species, indicated by a few mutilated bones in the Wealden (*ante*, p. 440). Many species, inferred from footprints on sandstone of the Triassic period (*ante*, p. 556) ??
REPTILES	*Marine*;—Ten genera, including above fifty-two species. *Terrestrial* and *Fluviatile*;—Twenty-four genera, comprising between forty and fifty species. *Flying*;—One genus, containing sixteen species.

Here, then, the classes Mammalia and Aves, which constitute the essential features of the existing terrestrial faunas of almost all countries, are represented through a period of time of incalculable duration, by two diminutive quadrupeds, and by uncertain vestiges of one genus of birds, and problematical foot-prints of bipeds on the rocks; while every where, bones, teeth, and entire skeletons of reptilian forms, adapted for aerial, terrestrial, and aquatic existence, afford unequivocal proofs that the air, the land, and the waters, were tenanted by cold-blooded vertebrate animals. In the succeeding tertiary ages, the fossil remains of reptiles belong to species of existing types, and are associated with those of mammiferous quadrupeds; thus, in the eocene strata of the Himalayahs, bones of living species of gavials and tortoises are imbedded with the skeletons of elephants, horses, and deer.

Now, if we admit to the utmost extent, the effect of causes that may be supposed to have operated to the exclusion of the remains of mammalia from the secondary formations, still the overwhelming preponderance of the reptile tribes, both on the land and in the waters, is most striking. And here we may inquire whether this remarkable phenomenon warrants the hypothesis which some eminent geologists have advanced, namely, that during the periods antecedent to the eocene, the earth was not adapted for the existence of mammalia ?—that it was in a state of turbulence and convulsion, which colossal reptile forms were alone calculated to endure ; that it was a half-finished planet, unsuitable for warm-blooded animals, and that its atmosphere was incapable of supporting the higher types of animal organization ? The probability that birds existed in the country of the Iguanodon—the certainty that marsupial and insectivorous mammals were the contemporaries of the Megalosaurus and Pterodactyles—that trees and plants, of genera which now grow in regions abounding in birds, and warm-blooded quadrupeds, flourished throughout the " Age of Reptiles," are facts which appear to me fatal to such a hypothesis, and to prove that the general temperature of the earth, and the physical constitution of the sea, and the atmosphere, were not essentially different from those which now prevail. That the class of reptiles was developed throughout the periods embraced in this review, to an extent far beyond what has since taken place, cannot, I conceive, by any legitimate process of reasoning be disputed ; but I do not think that in the present state of our knowledge, any satisfactory explanation of this extraordinary fact can be offered.

31. OBJECTIONS CONSIDERED.—There are persons who, with one of the Bridgewater essayists (Mr. Kirby*),

* Seventh Bridgewater Essay. In 1831, I transmitted a popular summary of the evidence bearing on this highly interesting question, with the title of " The Age of Reptiles," to Professor Jamieson, who published it in the " Edinburgh Philosophical Journal." This unpretending paper brought upon me an attack by the Rev. J. Kirby, in his " Bridgewater Essay ;" in which the reverend author supposes that there is a subterraneous world of reptiles, in which the Iguanodon still flourishes ! ! and the occurrence of a vertebra of the Ichthyosaurus in diluvial gravel, is affirmed to be a proof of the modern existence of that reptile ! ! ! As Dr. Buckland's Essay follows that of Mr. Kirby, the reader has the bane and antidote both before him, and

oppose these conclusions, and have recourse to the most strange conceits to account for the phenomena on which they are founded. But it is for those who refuse their assent to deductions made with the greatest caution, and derived from an overwhelming mass of evidence, to explain the entire absence of all traces, not only of Man, but of the whole existing species of animals and vegetables, in the ancient deposits; while there is not a river, or stream, which does not daily imbed the remains of the present inhabitants of the globe. But however future discoveries may modify this hypothesis, they cannot invalidate the fact, that there is no country on the face of the earth with such an assemblage of animal life, as that possessed by the regions whence the delta of the Wealden was derived; nowhere is there an island or a continent inhabited by colossal reptiles only, or where reptiles usurp the place of the large mammalia. We have seen that this feature in the zoology of that remote period was not confined to the country of the Iguanodon; in every part of the world where geological researches have extended, this wonderful phenomenon appears—the absence of mammiferous animals. The bones of reptiles of enormous size, are the only animal remains that occur in any considerable number. It is, therefore, manifest, that there was a period when oviparous quadrupeds of appalling magnitude, were the chief possessors of the lands, of which any traces remain in the strata that are accessible to human observation. I do not, however, mean to aver, that reptiles, and reptiles only, were the occupiers of every Island and Continent; but that it appears from the most irrefragable testimony, that the reptile tribes, during the secondary periods, were developed to an extent of which the present state of animated nature affords

I should on this occasion have passed over the unjust strictures of Mr. Kirby in silence, had they not been repeated in a late edition of the "Bridgewater Essays."

no example. It must be acknowledged that the proposition is astounding, and I do not feel any surprise, that many intelligent persons, whose attention has not previously been directed to geological inquiries, should hesitate to admit its correctness; but the conclusion is drawn from such an immense accumulation of facts, corroborated by observations made in every region of the earth, as to compel assent, in spite of all our preconceived opinions. We may, indeed, call up from the depths of our ignorance, hypotheses as marvellous as the phenomena they are intended to explain, but which a very slight examination of the facts before us would prove to be utterly untenable.

32. CONCLUDING REMARKS.—There is another objection to which I would allude, for I do not think with some, that the errors, or prejudices, of those who differ from us should be treated with silence or contempt; but, rather, that it is our duty to explain, again and again, the foundation of our belief, in the hope and assurance that we shall at length remove the erroneous opinions of persons, whose scepticism arises from their imperfect acquaintance with the subject. It has been insisted upon by those whose views are limited to the present state of the globe, that the supposition of the earth having been peopled by other creatures before the existence of the human race, is incompatible with the evident design of the Creator, and derogatory from the dignity of Man, for whose pleasure and necessities they assume all living things were created. But this inference is utterly at variance with what we know of the living world around us: everywhere we see forms of animated existence utterly unconscious of the presence of Man, and endowed with faculties and sensations wholly dissimilar from our own. Thus, while in the beautiful language of Scripture, we are told that not a sparrow falls to the ground without our heavenly Father's notice, a philosophical examination of the present constitution of nature, would alike condemn

such vanity and presumption. For my own part, feeling, as I do, the most profound reverence, and the deepest gratitude to the Eternal Being, who has given unto me this reasoning intellect, however feeble it may be; and believing that the gratification and delight experienced in the contemplation of the Wonders of Creation here, are but a foretaste of that inexpressible felicity which, in a higher state of existence, will be our portion hereafter, I cannot but think that the minutest living atom, which the aided eye of man is able to explore, is designed for its own peculiar sphere of enjoyment, and is alike the object of His mercy and His care, as the most stupendous and exalted of His creatures.

"Le même Dieu créa la mousse et l'Univers."

In nothing, perhaps, are we more mistaken, than in our estimate of the happiness enjoyed by other beings; to employ the beautiful simile of a distinguished author,—"As the moon plays upon the waves, and seems to our eyes to favour with a peculiar beam one long track amidst the waters, leaving the rest in comparative obscurity, yet all the while she is no niggard in her lustre—for although the rays that meet not our eyes, seem to us as though they were not, yet she, with an equal and unfavouring loveliness, mirrors herself on every wave; even so, perhaps, happiness falls with the same power and brightness over the whole expanse of being, although to our limited perceptions it seems only to rest on those billows from which the rays are reflected back upon our sight."* And if we admit, as all must admit who for one moment consider the marvels which Astronomy has unfolded to us, that there are countless worlds around us inhabited by intelligences of whose nature we can form no just conception, surely the discoveries of Geology ought not to be rejected because they instruct us,

* Sir E. B. Lytton's "Eugene Aram."

that ere man was called into existence, this planet was the object of the Almighty's care, and teeming with life and happiness.

Thus Geology reveals the sublime truth, that through periods of incalculable duration, our globe was the abode of myriads of living creatures, enjoying all the blessings of existence, and which at the same time were the destined instruments for the elaboration of the materials, by which the surface of the earth was rendered, in the course of innumerable ages, a fit temporary abode for intellectual and immortal beings!

LECTURE VI.

ON CORALS AND CRINOIDEA.

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1. INTRODUCTORY. 2. Organic and Inorganic Bodies. 3. Distinction between Animals and Vegetables. 4. Nervous System and Sensation. 5. Diversity of Animal Forms. 6. Animal nature of Zoophytes. 7. Cilia, or vibratile Organs. 8. Hydræ, or Fresh-water Polypes. 9. Elementary organic Structure. 10. Analogy not Identity. 11. The Flustræ. 12. Food of Zoophytes. 13. Nature of Coral Zoophytes. 14. Corals, or Polyparia. 15. Geographical distribution of Corals. 16. Sertulariæ, or Vesicular Corallines. 17. The Gorgonia. 18. The Red Coral. 19. Tubipora, or Organ-pipe Coral. 20. Madrepores. 21. The Actinia, or Sea-Anemone. 22. Caryophyllia and Turbinolia. 23. Fungia. 24. Astræa and Pavonia. 25. Meandrina, or Brain Coral. 26. Appearance of living Corals. 27. Coral Reefs. 28. Coral Reef of Loo-Choo. 29. Coral Islands. 30. Formation of Coral Islands. 31. Montgomery on Coral Islands. 32. Fossil Zoophytes. 33. Ventriculites. 34. Zoophytes of the Oolite and Lias. 35. Corals of the Palæozoic Formations. 36. Coralline Marbles. 37. The Crinoidea. 38. Structure of the Crinoidea. 39. Encrinites and Pentacrinites. 40. Derbyshire Encrinital Marble. 41. The Lily Encrinite. 42. Pear Encrinite of Bradford. 43. Pentacrinites and Actinocrinites. 44. Pentremites and Cystidea. 45. Concluding Remarks.

1. INTRODUCTORY.—In many of the deposits of the Secondary formations reviewed in the last discourse, a large proportion of the fossils consisted of those interesting types of animal organization, the Polyparia, Crinoidea, and other zoophytes: some of the oolitic strata, as for example the *Coral-rag*, being wholly made up of corals ; while many of the limestones and shales of the Lias, equally abounded in Encrinites, Pentacrinites, and other forms of the Crinoidea. In the more ancient palæozoic formations, to the examination of which our attention will hereafter be directed, we shall find these organisms in still greater profusion ; entire mountain chains consisting of the consolidated remains of corals, and vast tracts, of limestones composed of the mineralized skeletons of the Lily-shaped animals.

To enable the unscientific reader to comprehend the origin and formation of these ancient fossiliferous rocks, I therefore purpose devoting the present Lecture to a general view of the natural history of some of the recent animals of this class, and a brief notice of the most characteristic fossil species.

2. ORGANIC AND INORGANIC BODIES.—The beautiful world in which we are placed is every where full of objects presenting innumerable varieties of form and structure, of action and position ; some of them being inanimate or inorganic, and others possessing organization or vitality. The organic kingdom of nature, in like manner, is separated into two grand divisions, the animal and the vegetable. The differences between organic and inorganic bodies are numerous and manifest ; but it will suffice for my present purpose to mention a few obvious and familiar characters. All the parts of an inorganic body enjoy an independent existence; if I break off a crystal from this mass of calcareous spar, the specimen does not lose any of its properties, it is still a group of crystals as before ; but if a branch be separated from a tree, or a limb from an animal, each is rendered imperfect, and the parts removed suffer decomposition,—the branch withers, and the limb undergoes putrefaction. If crystals, which may be considered the most perfect models of inorganic substances, be formed, they will remain unchanged, unless acted upon by some external force of a chemical or mechanical nature ; within, every particle is at rest, nor do they possess the power to alter, increase, or diminish : they can augment by external additions only, and decrease but by the removal of portions of their mass.*

* These remarks must be taken in a general sense only, since recent experiments have demonstrated that the molecules of inorganic matter undergo modification by the slightest action of light, and variation of temperature.

"Prismatic crystals of zinc are changed in a few seconds into octahedrons by the heat of the sun. We are led from the mobility of

But organic bodies have characters of a totally different nature; they possess definite forms and structures, which are capable of resisting for a time the ordinary laws by which the changes of inorganic matter are regulated, while internally they are in constant mutation. From the first moment of the existence of the plant or animal to its dissolution there is no repose; youth follows infancy,—maturity precedes age; it is thus with the moss and the oak,—the monad and the elephant,—life and death are common to them all.

Animals and vegetables also require a supply of food and air, and a suitable temperature, for the continuance of their existence; and they are nourished by fluids elaborated by appropriate organs, and transmitted through suitable vessels. In the germ of an animal or a vegetable, there is a vital principle in action, by which are developed in succession the ordained phenomena of its existence. By this power the germ is able to attract towards it particles of inanimate matter, and bestow on them an arrangement widely different from that which the laws of chemistry or mechanics could produce. The same power not only attracts these

fluids to expect great changes in the relative positions of their molecules, which must be in perpetual motion even in the stillest water or calmest air; but we were not prepared to find motion to such an extent in the interior of solids. We knew that their particles were brought nearer by cold or pressure, or removed farther from one another by heat; but it could not have been anticipated that their relative positions could be so entirely changed as to alter their mode of aggregation. It follows from the low temperature at which these changes are effected, that there is probably no portion of inorganic matter that is not in a state of relative motion. Prismatic crystals of sulphate of nickel exposed to the summer heat, in a close vessel, had their internal structure completely altered, so that when broken open they were composed internally of octahedrons, with square bases. The original aggregation of the internal particles had been dissolved, and a disposition given to arrange themselves in a crystalline form."—*Mrs. Somerville, On the Connexion of the Sciences*, p. 171.

particles, and preserves them in their new situations, but is continually engaged in removing those which might by their presence prevent or derange its operations; and, on the other hand, so soon as the vital principle deserts the body which it has animated, the latter immediately becomes subjected to the agencies which act on inorganic matter: "in obedience to the power of gravitation the bough hangs down, and the slender stem bends towards the earth,—the animal falls to the ground,—the pressure of the upper parts flattens those on which they rest,—the skin becomes distended, and the graceful outlines of life are changed for the oblateness of death;"*—the laws of chemistry then begin to operate,—putrefaction takes place,—and, finally, dust returns to dust, and the spirit of Man to Him who gave it.

3. Distinction between Animals and Vegetables.—I have thus briefly described a few of the phenomena peculiar to organic existence; it will now be necessary to offer some remarks on the distinguishing characters of animals and vegetables, for unless we have a clear perception of the phenomena peculiar to each, we shall not obtain correct ideas of the nature of zoophytal organization.

When we compare together those animals and vegetables which are considered as occupying the highest stations in each kingdom, we perceive that they differ from each other in particulars so obvious and striking, as not to admit of question. The horse, and the grass upon which it feeds, —the bird, and the tree in which it builds its nest,—are so essentially distinct from each other, that we perceive at once that they belong to distinct classes of organic nature. But it is far otherwise when we descend to those animals and plants which occupy the lowest stations in vitality: here the functions to be performed are but few, the points of difference obscure, and it requires a correct knowledge of the laws of organization to enable us to

* Dr. Fleming; Philosophy of Zoology.

determine, with any degree of precision, where animal life terminates, and vegetable existence begins. The Lichen which grows on the stone, and the Zoophyte attached to the rock, present but little difference to the common observer: both are permanently fixed to the spot on which they grow, from the earliest period of their existence to their dissolution; and in the vegetable dried by the heat of the sun, and the coralline shrivelled up from the absence of moisture during the ebb of the tide, he would seek in vain for those characters which would assign the one to the vegetable, and the other to the animal kingdom.

4. Nervous system and sensation.—My limits will not permit me to dwell on the distinctions which exist between animals and vegetables in their chemical composition, nor on the different influence produced on the atmosphere by their respective agency: and I must content myself with explaining the remarkable endowment which is supposed to be peculiar to animal organization, namely, that of *sensation*, and to be dependent on that structure which is termed the Nervous, or medullary system.

When any object comes in contact with my finger I am sensible of its presence, and the finger is said to possess sensation: but if I compress, or cut across the nerve which passes from the spinal marrow to the arm, this faculty of sensation is suspended or destroyed: the same object may come in contact with my finger as before, but no feeling is excited indicating to me its presence. This phenomenon is well known, for every one must sometimes, in lying or sitting, have compressed the nerve of the arm or thigh, and occasioned a temporary numbness and loss of accurate feeling in the limb. I perceive, then, by my own experience, that sensation is inseparably connected with the presence and condition of the nerves; and that in Man and the vertebrated animals, the nervous influence is developed and transmitted by means of the brain and spinal marrow.

In examining the other divisions of the animal kingdom, the presence of a nervous system, more or less developed according to their respective intellectual and physical endowments, may be detected. In those of the higher orders, nervous filaments can be distinctly traced, from their origin in the brain or spinal marrow, to their distribution in the various parts to which they communicate sensation, and to the organs to which they impart the influence necessary for the performance of their several functions. But in proportion as the systems of absorbing, secreting, and circulating vessels, become less, a corresponding diminution takes place in the nervous fibres, till at length both vessels and nerves elude our finite observation, and we are left to infer from analogy, that, since sensation depends upon the presence of nerves, and the smallest animals evidently possess sensation, a nervous system exists in the minutest Monad which the highest power of the microscope enables us to descry.*

In the largest and most complicated vegetable organisms, no traces of nerves are perceptible, nor of any substance which can be considered as at all analogous in structure or function: it is therefore concluded, that as vegetables are destitute of nerves, they are likewise wanting in the faculty we term sensation.†

* Hence Rudolph, the celebrated physiologist, terms those animals in which no traces of *nervine*, or nervous matter, can be detected, the *Cryptoneura,* or hidden nerved.

† Although the definition here given is sufficient for our present purpose, yet it is necessary to state, that in a more rigorous and philosophical view of the subject, a line of demarcation between the vital phenomena exhibited by animal and vegetable organisms cannot be established. The possession of a stomach or digestive sac, and the power of locomotion, formerly thought to be peculiar to animals, are no longer regarded as such. Even the difference in the chemical processes effected by plants and animals,—namely, the absorption of carbonic acid and the evolution of oxygen by the former, and the opposite

But the nerves not only bestow feeling, they also confer the power of voluntary motion; and if the organs to which the motor nerves proceed be suitably constructed, they enable the animal to effect progression, or in other words, to change its situation from one place to another. As we descend in the scale of creation, we find many animals destitute of that power, and living on the same spot from the commencement to the termination of their existence; and all these creatures are inhabitants of the water.

Such, then, are the essential characters of animals—an external determinate form, gradually developed, with an internal organization possessing vessels for effecting nutrition and support, and capable of attracting and assimilating particles of inorganic matter; combined with a nervous system communicating sensation and voluntary motion; a certain term of existence being assigned to determinate forms—in other words, a period of life and death.

5. Diversity of Animal forms.—Animals are as varied in form and magnitude as the imagination can conceive; from the god-like image of Man, to the globule of jelly that floats upon the wave—from the Elephant and the Whale, to the Insect and the Animalcule, of which millions may be contained in a drop of water. In fact, so numerous and dissimilar both in form and structure are the animal organisms that exist on the earth, that the opinion of Astronomers that the inhabitants of the worlds around us, must, from the different densities and conditions of the respective planets, be totally distinct and unlike any that are known

effects produced by the latter—though a very general, is not a constant character; for some animals evolve oxygen; and from all the parts of plants which are not green, carbonic acid is exhaled: and when light is removed from the plant, the same thing happens every where. See *Dr. Bence Jones's Gulstonian Lectures*, for 1846.

to us, cannot be considered as incredible or marvellous.* But of all the shapes in which animal existence presents itself on our globe, none are more extraordinary, or unlike what is commonly conceived of living beings, than those of the compound creatures which are described by naturalists under the name of *Zoophytes*, or Animal-plants, and familiarly known in their varied forms by the names of Corals, Madrepores, Sponges, Sea-anemones, Dead-men's-fingers, Sea-fans, &c.

6. Animal nature of Zoophytes.—It was in this town (Brighton) that in the year 1752, the animal nature of many of the Zoophytes which abound on the Sussex coast, was first established. Mr. Ellis, an eminent naturalist, was engaged in forming a collection of marine plants, and having occasion to examine some of the specimens through a powerful microscope, he was astonished to find that the Sponges, at that time supposed to be vegetables, possessed a system of pores and vessels through which the sea-water circulated; and that many of the Corallines exhibited cells, from which tentacula or feelers were constantly protruding, and then suddenly retracting, as if seizing and devouring prey. Subsequent observations have proved that the substance we call sponge is the skeleton, or support, of a vascular substance which invests it, and which may be considered as the flesh of this animal. When viewed through the microscope, innumerable pores are seen on the surface of the Sponge constantly imbibing salt water, which circulates throughout the mass, and is finally rejected from the large openings; this water doubtless contains the living atoms that constitute the food of this zoophyte, but which are so minute as to elude observation.

The Sponges, however, approach so closely in their structure to certain plants, that many eminent naturalists

* See Thoughts on Animalcules, or a Glimpse of the Invisible World revealed by the Microscope, p. 7.

of the present day refer them to the Vegetable kingdom; thus Professor Owen expresses his opinion, that if a line could be drawn between animals and vegetables, the Sponges should be placed among the latter. But these bodies appear to me to hold an intermediate place—to be on the boundary line, that intervenes between the two grand divisions of animated nature; they are, in short, true Zoophytes or Animal-plants; it will, therefore, be instructive to dwell a brief space on the investigation of their structure, and economy.

The living Sponge, when highly magnified, exhibits a cellular tissue, permeated by pores, which unite into cells, or tubes, that ramify through the mass in every direction, and terminate in larger openings. In most Sponges the tissue is strengthened and supported by spines or spicula of various forms, and which, in some species, are siliceous, and in others calcareous.* The minute pores through which the water is imbibed, have a fine transverse gelatinous net-work, and projecting spicula, by which large animalcules or noxious particles are excluded; water incessantly enters into these pores, traverses the cells or tubes, and is finally ejected from the large vents. But the pores of the sponge have not the power of contracting and expanding, as Ellis supposed; the water is attracted to these openings by the action of instruments of a very extraordinary nature, by which currents are produced in the fluid, and propelled in the direction required by the economy of the animal.

7. Cilia,† or vibratile organs. — Although these organs, which are termed *Cilia*, from their hair-like appearance, are not confined to the class of animals which form the subject of this inquiry, yet they play so important a part in the economy of the Zoophytes and Crinoidea, that it will be necessary to define their structure and functions. These

* See Medals of Creation, p. 264. † From *cilium*, an eye-lash.

processes resemble very slender fibres or hairs, and are only visible under a powerful microscope. They are situated on parts habitually in contact with water or some other fluid, and possess the power of performing a rotatory or circular oscillation with great rapidity, by which they produce currents and eddies in the surrounding fluid.

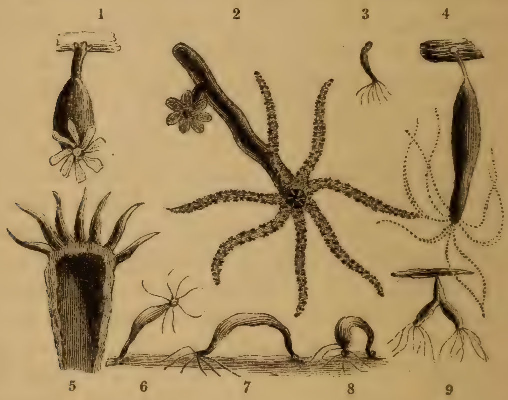
When a drop of water containing Infusoria or other animalcules is brought under the microscope, it is seen that as the creatures move along, every particle of foreign matter near them is agitated, a phenomenon indicating eddies in the water. When the Infusoria remain stationary, the currents are more distinct, and evidently take certain directions, causing the particles of matter to run in a stream to and from the animal. If a very high magnifying power be employed, transparent filaments will be distinguished projecting from the surface of the Animalcules, and moving with extreme rapidity. These are the Cilia, which serve to assist in progression, and when the animal is stationary, impel the water in currents through the cavities and tubes on which they are distributed: these must not be mistaken for the tentacula, or feelers, for they are fringes of delicate fibres investing those instruments, and the internal surfaces of other organs. The Cilia are so minute, that their outward form, position, and the direction of their motions only can be detected, their internal structure eluding observation. In the simplest animal organisms they are the organs by which motion and respiration are effected, and the food necessary for nutrition obtained. But they exist also in Man and the higher orders of vertebrata, and are the instruments by which many of the most important functions of the animal economy are performed. As we cannot separate the idea of muscular fibre from animal motion, it is conjectured that the Cilia are impelled by definitely arranged muscles: and Ehrenberg believes he has detected these muscles in some of the larger Infusoria.* The number of the cilia, even in an animalcule invisible to the naked eye, is almost incredible ; Dr. Grant calculates that a single polype of a Flustra has 400 millions.

8. THE HYDRA, OR FRESHWATER POLYPE.†—Before describing the zoophytes which are the immediate subject of this lecture, I would call your attention to one of the most simple forms of animal life, that abounds everywhere in freshwater streams, and being relatively of considerable size, will afford a convenient illustration of some of the vital phenomena exhibited in the coral zoophytes that give rise to reefs and islands in the seas of warm climates. This is the Hydra, or freshwater polype, of which several kinds inhabit our ponds, rivulets, &c. They are generally attached to the stems and leaves of aquatic plants ; and the largest species when in an expanded state is from a quarter to half an inch long, and of the size of a hog's bristle ; it is constricted at the end attached to the plant, and has an aperture or mouth at the free extremity, from around which proceed from six to ten long delicate tentacula (*Lign.* 132, *fig.* 4). The Hydræ present an example of a highly endowed organism of the simplest structure ; the whole animal consisting merely of a gelatinous, transparent, open cylinder, or tube, contracted at one extremity, and having the margin of the other prolonged into tubular tentacula. It is, in fact, a stomach, or digestive sac, with no appendage but the instruments for seizing its prey. A vertical section (*Lign.* 132, *fig.* 5) highly magnified, shows the interior of the receptacle for the food, the relative thickness of its substance, and the

* See the representation of the Cilia on the rotatory organs of the Rotifer or Wheel-animalcule in "Thoughts on Animalcules," p. 35.

† Polype, or polypus (*many feet*), is a name derived from the tentacula, or processes which in some species serve for progression, in others for respiration.

manner in which the tentacula are formed by an extension of the upper margin. The Hydra is endowed with vitality in a very extraordinary degree, and its substance is highly sensitive and contractile in all its parts. It fixes itself to other bodies by the small end of the tube, and expands and contracts at pleasure. These enlarged drawings (*Lign.* 132) represent polypes in different positions and



LIGN. 132.—HYDRÆ OR FRESHWATER POLYPES.

(*Drawn by Miss Ellen Maria Mantell.*)

Fig. 1. *Hydra fusca* magnified, the tentacula partially expanded. 2. Two Hydræ on the same base, one contracted, the other expanded. 3. *Hydra viridis*, natural size. 4. Hydra, with the body enlarged from its containing food. 5. Vertical section of *Hydra viridis*, highly magnified. 6, 7, 8. Hydræ in various states of progression. 9. A double Hydra, produced by the vertical section of a single one.

states of contraction. The mode of progression is shown in *figs.* 6, 7, 8; it is effected by the bending of the body into a curve, and holding by the tentacula; the base is then brought into contact with the fixed point, and the tentacula are again projected forwards. The Hydra can greatly elongate the body, and also contract itself into a small globular mass, as in the uppermost polype in *fig.* 2.*

The most extraordinary vital endowment possessed by these freshwater polypes, is that of the reproduction of lost parts to an almost unlimited extent; even to the formation of several perfect animals from the separated pieces of a single individual. If the body is split in half, each portion grows into a complete Hydra, as is shown in this drawing (*fig.* 9); and as if there were no limits to its transformations, the creature may be turned inside out, and that which was the surface of the stomach will become the epidermis, and the outer skin form the lining of the new stomach, and carry on the process of digestion! †

9. ELEMENTARY ORGANIC STRUCTURE; CELLS.—The interpretation of these phenomena is to be found in the peculiar organization of the Hydra, its entire structure being nothing more than an aggregation of cells. A vertical section of a Polype (*Lign.* 132, *fig.* 5,) shows the internal cavity or digestive sac, the relative thickness of the substance of the body, and the manner in which the arms are formed by a prolongation of the upper part into hollow processes. This animal is, in fact, a simple sac or pouch formed of a congeries of cells, for the reception and assimilation of food. The cells lining the stomach select and absorb the nutritious particles, and the tube then spontaneously contracts and casts out the residue of digestion. This organization is analogous to that of the simplest condition of the vegetable kingdom, the *Cellulosæ*: for even the large *Fuci*, or sea-weeds, consist only of cells. The freshwater *Confervæ* are merely jointed films composed of cells, containing granules or lesser cells. A cell bursts,

* See my "Thoughts on Animalcules," Pl. I. for coloured figures of the Hydræ.

† M. Trembley of Geneva, in 1740, first observed this wonderful property of the Hydra. See his charming work, "Mémoires pour servir à l'Histoire d'un Genre de Polypes d'Eau douce." A Leide, 1744.

the granules escape, and float in the water till they become fixed to some other body ; they then reproduce cells, which are aggregated after the same pattern as in the parent plant. The common mould or mustiness is a cluster of plants formed of cells only ; and there are some vegetables in which the entire plant consists of but *one isolated cell;* such are the yeast fungus (*Tortula cerevisiæ*), and the red snow (*Leparia nivalis*). In these examples we see that all the functions of vegetable life, namely, absorption, assimilation, the fixation of carbon from the atmosphere, respiration, exhalation, secretion, and reproduction, are effected by one single cell. Even in the highest and most complicated orders of vegetables, in which there is a variety of organs adapted for the performance of different offices, these functions are effected by the agency of cells, which obtain materials of formation and support from the ordinary chemical agents around them. Thus an aggregation of simple cells forms the cellular tissue : a fusion or blending of several cells produces the vessels, and so forth ; and by cells are elaborated the gum, resin, oil, starch, gluten, &c : and by cells specially endowed, are secreted the narcotic of the poppy, the deadly poison of the nightshade, and the stimulant aromatic of the clove.

In like manner, in animal structures, all the various processes of vitality are performed by cells or globules, varying in size from infinite minuteness to forms visible to the unassisted eye. Thus one system of cells secretes the bile, another the adipose substance, another the nervous matter, and so forth ; but how these special products are formed by cells apparently of similar organization we know not. Whether the special endowment belonging to the system of cells of a particular organ depends on the intimate structure of the wall or tissue of such cells, and this structure be so attenuated and infinitesimal as to elude our observation ; or whether it results from the transmission of some peculiar modification of that mysterious vital force we term nervous influence, are questions to which, I apprehend, no satisfactory reply can be given.

In fine, a minute globular cell is typical of the common germ from which all organic fabrics proceed. All animals and plants, therefore, may justly be regarded as definite aggregations of cells, endowed with specific properties in the different types, and subjected to a never-varying law of development; and in animals, as well as in plants, there are certain kinds in which the entire organism consists of but a single cell;* and others in which each individual is but a cluster of such cells arranged in a definite manner. These mere aggregations of cells perform all the functions of animal life, viz., the maintenance of a particular form for a certain period, the elaboration of materials of support from food, locomotion, and the perpetuation of the species; hence these animals, like the simplest plants, may be divided without losing their vitality, and every part may become a perfect individual. To this class belongs the Hydra, and the above exposition of its structure renders the production of several animals from the vivisection of an individual, perfectly intelligible.

10. Analogy not Identity.—And here I must briefly comment on the doctrine of the *law of development*, as it is termed, so speciously, but unphilosophically, advocated in a recent work;† in which it is attempted to show, that all the varied forms of organic life are the result of a law, by which is produced an unbroken chain of gradually exalted organization, from the crystal to the globule, and thence through successive stages of the polype, mollusk, &c. up to Man.‡

* The Monads: see "Thoughts on Animalcules," Plate II.

† Vestiges of the Natural History of the Creation.

‡ The following remarks of Sir John Herschel on this theory are too important to be omitted. "The transition from an inanimate

The following remarks will serve to show the fallacy of this reasoning. Though it is an established physiological axiom, that cells are the elementary basis, the ultimate limit to which we can trace all animal and vegetable structures, and that the varied functions in which organic life essentially consists, are performed by the agency of cells not distinguishable from each other by any well-marked characters, there is not the slightest ground for assuming any identity between the primary cells of the simplest species of animals and vegetables ; much less between those of higher organization. The single cell which embodies vitality in the yeast fungus or the monad, is governed by the same immutable organic laws which preside over the complicated structure of Man and the other vertebrata : and the single cell which is the *embryotic* condition of the Mammal, has no more relation to the single cell which is the *permanent* condition of the Monad, than has the perfect animal into which the mammalian cell is ultimately developed. The cell that forms the germ of each species of organism is endowed with special properties, which can result in nothing but the fabrication of that particular species. There is an *analogy* between the human embryo and the monad of the Volvox, in that each consists of simple cells : but there is no more *identity* between the human and polygastrian cells than between the perfect Man and the mature Animalcule.*

crystal, to a globule capable of such endless organic and intellectual development is as great a step—as unexplained a phenomenon—as unintelligible to us—and in any human sense of the word as *miraculous*, as would be the immediate creation and introduction upon earth, of every species, and every individual. Take the amazing facts of Geology which way we will, we must resort elsewhere than to a mere speculative law of development for their explanation."—*Brit. Assoc. Reports for* 1845, p. 42.

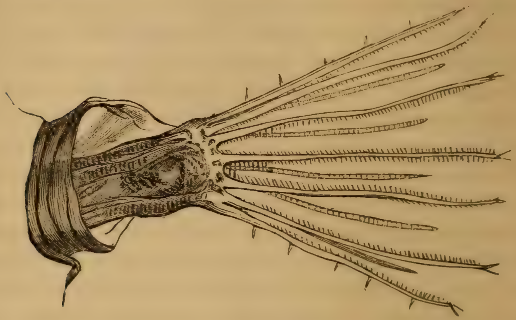
* See Notes to my Thoughts on Animalcules : and Westminster Review, No. XC. Art. "The Microscope and its Revelations."

11. The Flustra.—From this digression we return to the consideration of those zoophytes which possess a calcareous framework or support, and are termed *Corals;* and I will select one of the most simple and common forms in illustration of the subject. Most persons in their rambles along the sea-shore, must have noticed on the fuci, shells, and pebbles, patches of a white calcareous substance, which when closely examined appear like delicate lace-work: these apparently mere earthy particles, are clusters of the compound zoophyte termed *Flustra*, or *Sea-mat* (*See Plate* V. *figs.* 5, 6, 7, 8).

The Flustra, when taken alive out of the water, presents to the naked eye the appearance of fine net-work, coated over with a glossy varnish (*Pl.* V. *fig.* 5); with a glass of moderate power, the surface is discovered to be full of pores, disposed with much regularity (*Pl.* V. *fig.* 8). If a magnifying glass be employed, while the Flustra is immersed in sea-water, very different phenomena appear; the surface is found to be invested with a fleshy or gelatinous substance, and every pore to be the opening of a cell, whence issues a tube with several long feelers or arms (*Lign.* 133); these expand, then suddenly close, withdraw into the cells, and again issue forth; the whole mass being studded with these hydra-like forms. The Flustra thus constitutes, as it were, a family of polypes, each individual of which is permanently fixed in a calcareous cell, and the whole united by a common integument, by which the calcareous framework was secreted. Under a powerful microscope the form and structure of the animal of the Flustra may be easily distinguished. *Pl.* V. *fig.* 6, represents a single polype with its tentacula extended; and *fig.* 7, the same animalcule, withdrawn into its cell. The figure, *Lign.* 133, shows a polype protruded, under a much higher power.*

* This exquisite figure is from a memoir by Mr. Lister (Philos. Trans. 1834), on the structure and functions of the Tubular and

The body of the animalcule consists of a transparent sac or pouch, doubled on itself, and having at the mouth, or large external opening, ten or twelve tentacula fringed with cilia, which have the power of extending and contracting with great celerity.



LIGN. 133.—POLYPE OF FLUSTRA PILOSA; WITH ITS MOUTH AND CILIATED ARMS PROTRUDED FROM THE CELL.

(Magnified 150 times.)

The Flustræ present considerable variety in the form and arrangement of their cells. The most common species are found attached to marine plants, which they enclose, as it were, in a living sepulchre (*Pl.* V. *fig.* 5); others spread into foliated expansions, and have both sides covered with cells.* The prevailing hue is white, or a light fawn colour, but some species have a tinge of pink or yellow. They abound in every sea, and are not restricted by climate, occur in profusion along the sea-shores, and are found attached to the fuci that are thrown up from the pro-

Celullar Polypes. The observations were made at Brighton, and I had the pleasure of seeing the live zoophytes under the fine instrument constructed by Mr. Lister.

* See Dr. George Johnson's beautiful work on "British Zoophytes," for numerous figures and accurate descriptions of the British Flustræ, &c.

found depths of the ocean. The small parasitical species, when dried, appear like spots of a chalky substance on the sea-weed. The increase of the Flustra is thus described by Lamouroux :*—"When the animal has acquired its full growth, it flings from the opening of its cell a small globular body, which fixes near the aperture, increases in size, and soon assumes the form of a new cell; it is yet closed, bu, through the transparent membrane that covers its surface the motions of the polype may be detected; the habitation at length bursts, and the tentacula protrude, eddies are produced in the water, and conduct to the polype the atoms necessary for its subsistence."

12. THE FOOD OF ZOOPHYTES.—However improbable it may appear to the mind unaccustomed to investigations of this nature, that beings so minute as those under examination should prey upon living forms yet more infinitesimal, the fact is nevertheless unquestionable. It is even possible to select the food of animalcules much smaller than the polypes of the Flustra, and thus exhibit their internal structure. This experiment is easily shown under a good microscope, and the animalcules termed *Vorticellæ*, a very abundant family of Infusoria, are best adapted for the purpose. Immediately on a minute particle of a very attenuated solution of pure carmine or indigo being applied to a drop of water containing a group of the *Vorticellæ*,† the most beautiful phenomena are observable. Currents are excited in the fluid in all directions, by the rapid motion of the cilia which form a crown round the anterior part of the body of the animalcules, and the particles of indigo are seen

* "Corallina;" an excellent abstract of Lamouroux's "Memoir on the Flexible Corals" (one vol. 8vo. 1834), p. 43.

† The Vorticellæ are hyaline vasiform animalcules, attached by a slender peduncle at the base, and having rows of cilia disposed in zones round the margin: these, when seen in some directions while in rapid motion, appear like wheels; hence they are commonly called Wheel-animals. See "Thoughts on Animalcules," Pl. III.

moving in different directions, but generally all converging towards the orifice or mouth, which is situated not in the centre of the crown of cilia, but between the two rows of these organs, which exist consecutive to one another. The attention is no sooner drawn to this interesting spectacle, than presently the bodies of the animals, which were before quite transparent, become dotted with distinctly circumscribed spots, of a dark blue colour, exactly corresponding to that of the moving particles of indigo. In some species, particularly in those which are provided with an annular contraction or neck, separating the head from the body, the molecules of indigo can be traced in a continuous line in their progress from the mouth to the internal cavities.

The animalcules termed *Monads*, may be considered as the lowest term of animal organization recognisable by man, being only from the 1,200th to the 24,000th part of an inch in diameter, and the powers of the microscope extend no farther; yet it is impossible to doubt that there are myriads of living forms more infinitesimal, some of which serve as food to these miniatures of life.*

13. Nature of Coral Zoophytes.—In the larger and free masses of Flustra, the decomposition of the animal substance after death is very manifest. This specimen of *Flustra foliacea*, which was dredged up twenty miles SS.W. of Brighton, in water eighteen fathoms deep, is a fine example of this brittle species; when first in my possession it was highly offensive from the emanations evolved

* "The size of the ultimate particles of matter must be small in the extreme. Organized beings, possessing life and all its functions, have been discovered so small that a million of them would occupy less space than a grain of sand. The malleability of gold—the perfume of musk—the odour of flowers—and many other instances might be given of the excessive minuteness of the atoms of matter: yet, from a variety of circumstances, it may be inferred that matter is not infinitely divisible."—*Mrs. Somerville*, p. 125.

during the decomposition of the animal matter. It is now a calcareous skeleton, with here and there portions of the shrivelled integument, but, of course, without any traces of polypes in the cells.

Let us now refer to our previous remarks, and inquire if the Flustra presents the essential characters of animal existence. Its polype possesses a determinate form, and has a calcareous skeleton covered by a soft fleshy substance, that can for a certain period resist chemical and mechanical agency. It is furnished with instruments capable of moving with great celerity, is susceptible of external impressions, and can expand and contract at will. Here, then, is evidence of sensation and of voluntary motion ; and although, from the extreme minuteness of the structure, nerves cannot be detected, yet there can be no doubt that it possesses a nervous, and also a circulatory system for effecting nutrition and reparation. We find, also, that when removed from the element in which it lived, the creature dies, and its soft substance, like the flesh of the larger animals, undergoes putrefaction; it has lost the vital principle by which it previously resisted chemical agency, and now submits to the effects of those laws which act upon inorganic matter ; the calcareous materials that composed its skeleton, and which, like the bones of mammiferous animals, were secreted by the soft parts, alone remain.

I would here particularly remark, that the stony support of all Zoophytes is formed by a similar process ; the hard substance called *coral*, being secreted by the integuments, or membranes with which it was permeated and invested, in like manner as the bones and nails in man are secreted by the tissues designed for that purpose, and acting without his knowledge or control. Nothing can be more erroneous than the popular notion that the cells of corals are built up by the polypes found in them, in the same manner as are the cells of wax by the Bee.

From what has been advanced, it is evident that the

Flustra is an aggregation of an immense number of individual polypes attached to a calcareous skeleton ; each of which is doubtless susceptible of pain and pleasure independently of the whole ; for we have a living proof in the Siamese twins,* that even in our own species there may be an united organization with separate nervous systems, and individual sensations ; and as it is certain that each Polype enjoys distinct volition, it is most probable that the sensations of each individual are independent of the general mass. There is, however, a common sensibility pervading the structure that binds together the community of zoophytes, and by which certain actions are performed irrespectively of the individual polypes. Thus the compound zoophytes termed *Pennatulæ*, or Sea-pens, upon the slightest touch withdraw themselves into the wet sand, and disappear: and the arborescent *Vorticellæ*† upon the microscope being agitated, instantly shrink down into a globular mass, and all appearance of the elegant animalcules a moment before so active, vanishes. In certain species of Flustra, *F. avicularia* for example, each cell is protected by a bivalve operculum, much resembling in form the beaks and head of a vulture ; and these appendages open and shut apparently without the control of the polype that occupies the cell ; their functions seem to be related to the horny axis that connects the group of independent living animalcules of which the entire compound zoophyte is composed, and not to the polypes themselves.‡

14. THE CORALS OR POLYPARIA.§—In the Flustra, then,

* See the Philosophical Transactions for 1830, p. 177.

† See "Thoughts on Animalcules," p. 49.

‡ The reader will find some highly interesting observations on this phenomenon in Mr. Darwin's "Journal of a Voyage round the World," chap. ix. p. 200.

§ *Polyparia.* The axis, framework, or skeleton of these groups of polypes is termed *polyparium*, or *polypidom* (polype-habitation) ; and those of a stony hardness are familiarly known as *Corals* : these names therefore refer to the durable skeleton of the zoophytes, and not we have the elements of zoophytal organization, and all the varied and extraordinary forms that will hereafter come under our notice, are but modifications of this type of animal existence. In some, the skeleton or support consists of earthy matter as in the Flustra, but solid and hard as adamant; in many examples it branches out like a tree (*Lign.* 136, p. 620) ; in others, constitutes hemispherical masses, having numerous convolutions on the surface, somewhat resembling in appearance the brains of quadrupeds (*Lign.* 138) ; and in many it forms an aggregation of tubes, terminating in star-like openings (Pl. VI. *fig.* 9). Among the branched varieties, some are covered by pores so numerous as to be called *Millepora;* in many, the openings are distant: some have star-like markings here and there; while in others, the whole surface presents a stellated structure. In many species the fleshy animal matter entirely covers and conceals the stony skeleton during life; in others, the latter becomes exposed, and forms a trunk, having branches covered by living polypes; while in another, and numerous division (of which the common *Sertularia* is an example), the skeleton is secreted by the *outer* surface of the soft parts, and constitutes an external protection to the polypes (Pl. V. *fig.* 1). In another family, the *Gorgonia* (*Lign.* 135), the skeleton is of a horny or ligneous texture, and flexible, bending to the motions of the waves; while in some it is jointed or articulated, as in the *Isis* (*Lign.* 136, *fig.* 3). Sometimes the skeleton is impressed with the cells, as in the Madrepores (*Lign.* 136, *fig.* 2); while in other species, as the Red Coral, the stem is smooth, and exhibits no traces of the peculiar structure of the animal,

to the polypes themselves; but in familiar writing the term Coral is often used to designate the entire living mass. The *Red Coral* forms a distinct genus called *Corallium.* In a fossil state the *polyparium* alone remains, except in a few instances. See "Medals of Creation," chap. viii.

the polype-cells being formed of the investing soft substance (Pl. V. *fig.* 9). Yet amidst all these varieties of form, the same essential characters are maintained; in all there is a skeleton or solid support, and a fleshy or gelatinous substance studded with polypes.

The *Flustra*, *Eschara*, &c. are called *Bryozoa*, or moss-animals, because their aggregated masses encrust other bodies like moss: their polypes, though, as we have already seen, exceedingly minute, are highly organized, their digestive organs being more complicated than in the other tribes of zoophytes. The polypes of the large calcareous masses that constitute the coral reefs of tropical seas, are of a lower organization, and resemble the common Sea-anemone (*Actinia*, Pl. VI. *fig.* 11); they are termed *Anthozoa*, or flower-animals. The lowermost group are the polypes in which digestion is performed by a simple sac or pouch like the common Hydra: these are classed as *Hydrozoa*, or hydra-like animals.*

From an analysis of the stony corals, it appears that their composition is very analogous to that of shells. The porcellaneous shells, as the Cowry, are composed of animal gluten and carbonate of lime, and resemble, in their mode of formation, the enamel of the teeth; whereas the pearly shells, as the Oyster, are formed of carbonate of lime and a gelatinous or cartilaginous substance, the earthy matter being secreted and deposited in the interstices of a cellular tissue, as in bones. In like manner some corals yield gelatine upon the removal of the lime; while others afford a substance in every respect resembling the membranous structure, obtained by an analysis of the nacreous shells.† A recent elaborate analysis of between thirty and forty species

* The reader interested in this subject should study that charming and classical work on Comparative Anatomy, Prof. Owen's "Hunterian Lectures," vol. i. lect. vii.

† Experiments of Mr. Hatchett.

of Corals by an eminent young American chemist (Mr. B. Silliman), has shown, contrary to expectation, that they contain a much larger proportion of fluorine than of phosphoric acid.*

15. GEOGRAPHICAL DISTRIBUTION OF CORALS.—I will first consider the geographical distribution of the Polyparia; in the next place, describe a few of the principal varieties; and, lastly, review the important physical changes effected by creatures so minute, and apparently so incompetent to produce any material alteration in the earth's surface.

The Corals are for the most part inhabitants of the ocean; many species prefer the immediate influence of atmospheric changes, and are seen on the rocks and plants left bare by the reflux of the tide, sometimes in such profusion that the whole surface appears one animated mass. At the period of the great equinoctial tides, when the sea retires from the rocks which it has overflowed for many preceding months, the Polyparia, when the waters first recede, are full of vigour, but languish as they lose their moisture, and perish if they remain long uncovered by the sea.

Some kinds are situated on the southern slope of the rocks; others, on the contrary, are attached to the opposite aspect, and never to the former. The larger forms are rarely found in places exposed to violent currents; it is in the hollows of the rocks, in submarine grottoes, in the shelter of large and solid masses, that these species attach themselves. Many appear fitted to enjoy the powerful action of the surges, their pliant branches bending to the

* Appendix to Mr. Dana's memoir on the "Structure and Classification of Zoophytes," Philadelphia, 1846. This volume is an Introduction to the "History of the Zoophytes collected by the American Exploring Expedition," now in the press: the publication of this work of the accomplished author is looked forward to with great interest by European naturalists.

movements of the waters, and floating in the agitated medium ; while others form immoveable rocks, which increase slowly but surely, till they become elevated above the surface of the waters, and constitute reefs and islands, as I shall hereafter describe.

The distribution of these animals is not solely regulated by the relative depths of the water ; like plants, they vary with the climate, and in cold latitudes the Cellariæ and Sertulariæ, with a few Sponges and Alcyonia, are alone to be met with. As we proceed to the 44th or 45th degree of northern latitude, their number increases, and Gorgoniæ, Sponges with loose tissue, and Millepores with foliated and fragile expansions, appear in profusion. A little farther, and the coral reddens the depths of the ocean with its brilliant branches, and is soon followed by the large Madrepores. It is not, however, before the 34th degree of northern latitude that the Corals become developed to the grandeur and importance which they afterwards attain, to the extent of a parallel southern latitude ; except in the waters of the Atlantic, around the Bermuda Islands, where corals abound, owing to the temperature induced by the influence of the Gulf-stream. It is therefore within the tropics, in a zone of more than 60 degrees expansion, that these beings, scarcely visible to the naked eye, exercise their empire, in a medium whose temperature knows no change; and from the depths of the ocean elevate those immense reefs, that may hereafter form a communication between the inhabitants of the temperate zones.* I proceed to describe a few of the principal forms.

16. THE SERTULARIA, OR VESICULAR CORALLINE.—The elegant arborescent *Sertulariæ* must be familiar to every one who has rambled by the sea-side. This branch of the Sea-pine coralline (*Lign.* 134), and which is shown magnified in *fig.* 2, exhibits the usual appearance of these

* Lamouroux.

zoophytes. The Sertularia consists of tubes united together, and having lateral apertures for the protrusion of each polype; one elegant species, the *Sertularia setacea*, is very

1 2

LIGN. 134.—SERTULARIA, OR VESICULAR CORALLINE.

(*Sertularia nigra, Dr. Johnston.*)

Fig. 1. Natural size. 2. A portion highly magnified.

abundant on the shores at Brighton after storms, being attached to fuci and other sea-weeds. This representation of a branch magnified sixty times (*Plate* V. *fig.* 1) shows the form of the polypes, which, when fully expanded, are of great beauty. On one occasion, when I was present, Mr. Lister was observing a living specimen, when a little globular animalcule swam rapidly by one of the expanded polypes; the latter immediately contracted, seized the globule, and brought it to the mouth or central opening by its tentacula; these gradually opened again, with the exception of one which remained folded, with its extremity on the animalcule. The mouth instantly seemed filled with cilia, that closed over the prey, which, after a few seconds, was carried slowly down into the stomach; here it was imperfectly seen, and soon disappeared.*

The *Campanulariæ*, so named from their bell-shaped

* Philos. Trans. 1834, p. 372.

cells placed on foot-stalks, are also abundant on our shores. *Pl.* V. *fig.* 2, is a magnified view of a branch of *Campanularia gelatinosa*, with several cells; in some the polypes are expanded, in others contracted. Examined alive under the microscope, currents of minute globules are seen constantly running along the tubes, induced by the action of the invisible cilia.

17. THE GORGONIA, OR SEA-FAN.—The *Gorgonia flabellum*, or Venus's fan (*Lign.* 135), is a flexible coralline,

LIGN. 135.—GORGONIA FLABELLUM; *one-twentieth nat. size.*
(*Drawn by Miss Ellen Maria Mantell.*)

which inhabits almost every sea, and frequently attains a height of four or five feet. When fresh from the water it is of a bright yellow colour. This species exhibits the usual structure of the corticiferous polyparia, or zoophytes which are composed of an internal axis or skeleton, of a tough horny consistence, having an external envelope or rind, that entirely invests the former. The Gorgoniæ present great diversity of form and appearance. This specimen from the West Indies (*Pl.* VI. *fig.* 2) is remarkable for its richness of colour, being a bright yellow, spotted with red; this species, (*Pl.* VI. *fig.* 3,) from the Mediterranean, has its pendant branches very elegantly disposed, and is of a purplish-lake colour; in both these examples the axis is black, and of the consistence of tough horn. Another beautiful species from the Mediterranean, (the *Gorgonia patula* of Ellis,) is of a bright red, and has the openings for the polypes disposed in two rows; a portion, highly magnified, is here represented, (*Pl.* V. *fig.* 3,) and exhibits several polypes in different states of protrusion.

These flexible Polyparia are attached to the rocks by an extended base, whose surface is usually deprived of the fleshy substance by which the other parts are invested. The stem which springs from the base, although in a few species simple, generally divides into branches, which are exceedingly various in their size and distributions:—double, single, anastomosed, pinnated, straight, and pensile; and the stems are either compressed, flat, angular, or cylindrical; but in all these modifications the same structure prevails—an axis, and an external crust or rind. The former is either horny, elastic, flexible, brittle, or pithy, and of a dark colour; the latter a soft fleshy substance, studded with pores, from which the polypes issue; this rind becomes earthy and friable when dried. In the *Isis*, which may be described as a Gorgonia with a jointed stem, this structure is well displayed, as in this branch of *Isis hippuris* (*Lign.* 136, *fig.* 3, p. 620), in which a portion of the cortical part is removed, and the axis exposed. In the water the various species present the most vivid hues of red, green, violet, and yellow. The Gorgoniæ inhabit deep water, and are found in every sea; but certain species appear to be restricted to tropical climates. Several species of this genus occur in a fossil state; a very beautiful species is often met with in the Maestricht limestone (*ante*, p. 320, *fig.* 5).

18. THE RED CORAL; *Corallium rubrum.*—I advance to the examination of the polyparia having an axis composed of a calcareous stony substance; and one genus of which possesses a skeleton of so beautiful a colour, and susceptible of so fine a polish, as to be largely employed for ornamental purposes. The Red Coral is a branched zoophyte, somewhat resembling in miniature a tree deprived of its leaves and twigs. It seldom exceeds one foot in height, and is attached to the rocks by a broad expansion or base. It consists of a brilliant red stony axis, invested with a fleshy or gelatinous substance of a pale blue colour, studded over with stellular polypes. This figure (*Pl.* V. *fig.* 9), represents a branch of Coral with several polypes, highly magnified, as seen alive in the water. The cortical or fleshy substance is removed at the extremities of the branch, and the red stony axis exposed. As the cells of the polypes are only composed of the soft animal matter which rapidly undergoes decomposition after death, no traces of their structure remain on the durable skeleton.

The Red Coral, as is well known, is of a very hard and durable texture; it is obtained by dredging in different parts of the Mediterranean and Eastern seas, and forms an important article of commerce. It varies much in hue, according to its situation in the sea: in shallow water it is of the most beautiful colour, a free admission of light appearing necessary for its full development. It is of slow growth; eight or ten years, in a moderate depth of water, being necessary for it to reach maturity. Arrived at this period, it extends but very slowly, and is soon pierced on all sides by those destructive animals which attack even the hardest rocks; it loses its solidity, and the slightest shock detaches it from its base. Becoming the sport of the waves, the polypes perish, their brilliant skeleton is exposed, and cast upon the shore ; the bright colour soon disappears, and the coral, reduced to fragments by the attrition of the waves, becomes mixed with the remains of shells and other marine exuviæ: in this state it is drifted inland by the winds, and assists in forming those accumulations of the spoils of the sea, which constitute many of the modern conglomerates described in a previous lecture (*ante*, pp. 85, 90).

19. Tubipora.—This group of corals is well known, from the elegance and beauty of one species (*Sarcinula musicalis*, or *Organ-pipe coral*), which is common in most collections. This coral is composed of parallel tubes, united by lateral plates, or transverse partitions, placed at regular distances ; (*Pl.* VI. *figs.* 7, 9) in this manner large masses, consisting of a congeries of pipes or tubes, are formed. When the animalcules are alive, each tube contains a polype of a beautiful bright green colour, and the upper part of the surface is covered with a gelatinous mass formed by the confluence of the polypes ; a magnified view of a polype and sections of two tubes, is here represented (*Pl.* VI. *fig.* 7). This species occurs in great abundance on the coast of New South Wales, of the Red Sea, and of the Molucca Islands, varying in colour from a bright red to a deep orange. It grows in the shape of large hemispherical masses, from one to two feet in circumference ; these first appear as small specks adhering to a shell or rock ; as they increase, the tubes resemble a group of diverging rays, and at length other tubes are produced on the transverse plates, thus filling up the intervals, and constituting a uniform tubular mass ; the surface being covered with a green fleshy substance, beset with stellular animalcules. The protruded polype of another beautiful species of Tubipore (*Tubipora rubeola*) is represented magnified, *Pl.* VI. *fig.* 4;

and a view of an expanded polype of the same seen from above, in *fig.* 6; the polype of another species of Tubipore is represented in *fig.* 12.

20. Madrepora. — In the Red Coral, no cells are formed by the hard skeleton to serve as a protection for the polypes; but in the family of branched, or arborescent calcareous polyparia, called *Madrepores*, the little cups or cells, with radiating lamellæ, in which the polypes are

Lign. 136.—Recent corals.

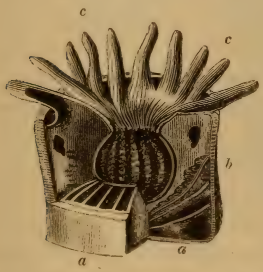
Fig. 1. A branch of *Oculina ramea.* 2. A branch of *Madrepora muricata.* 3. A branch of *Isis hippuris*: *a*, the cortical substance covered with pores, which are the cells of polypes; *b*, a branch deprived of its outer covering, and exposing the articulated axis or stem.

situated, are composed of the same substance as the axis. When the animals die, and the outer fleshy investment perishes, the coral is therefore found to be studded over with elegant, lamellated, stellular cells, variously formed and arranged in the different genera and species. In some the cells are very distinct; as in a Mediterranean species, the *May-blossom Coral* (*Oculina ramea, Lign.* 136, *fig.* 1); in others they are exceedingly minute, as in this common Madrepore (*M. muricata, Lign.* 136, *fig.* 2), from the West Indies. The white branched corals so numerous in collections belong for the most part to this group.

When alive in the water the Madrepores are invested with a fleshy integument of various colours: and each cell is occupied by a polype, as in the zoophytes previously examined. The appearance of a living Madrepore (*M. plantaginea*) with the polypes protruded, is shown in *Pl.* VI. *fig.* 5, and will serve to convey a faint idea of the beautiful appearance of the live corals in their native element.

21. The Actinia, or sea-anemone.—In another division of corals the cells are few, and of considerable dimensions, the polypes being of proportionate size, and bearing considerable analogy to the *Actiniæ*, or *Sea-Anemones*, which are so common on the rocks, and in the shallows on our sea shores; a few observations on these animals will therefore enable us to comprehend the nature of this group of polyparia. The Actinia, or Sea-animal flower, as it is popularly termed, appears, when quiescent, like a subglobular mass of tough jelly, of various tints of crimson, green, blue, or brown (*see Pl.* VI. *fig.* 11); when expanded it presents a broad disk, surrounded by tentacula, having in the centre a corrugated surface, which is contracted into a marsupial or purse-like form.

The Actiniæ are affixed to the rocks by a broad base, but they can detach themselves, and change their position; on the Sussex coast hundreds may be seen, at low water, in the hollows of the chalk-rocks which are left bare by the reflux of the tide. They are carnivorous and very voracious, feeding on the small fish, crustacea, and mollusca, that come within their reach. I have kept them for months in sea-water, supplying them daily with meat, which they greedily seized, drew into the sac, or stomach, and afterwards ejected perfectly colourless, having absorbed the juices, and left the tough, muscular fibre. The body of the Actinia is highly contractile and full of cells: the tentacula are hollow tubes, which the animal has the power of filling with sea-water, and thus causing them to protrude. The cells also contain water, with which the whole or any part of the body can be filled ; and I have observed that when the animal is desirous of shifting its situation, it distends one half of the body with water, then withdraws the base from the stone, and sinks to the bottom of the vessel in which it is contained. This plan of the internal structure of the Actinia (*Lign.* 137), will serve to illustrate these remarks. The surface of the stomach, and even the internal lining of the tentacula, are abundantly furnished with cilia ; these zoophytes have no durable skeletons.



LIGN. 137. — ILLUSTRATION OF THE STRUCTURE OF THE ACTINIA.*

a, a, The base by which the actinia attaches itself. *b, b,* Openings of cells which communicate with each other and with the tentacula. *c, c,* The tentacula. The surface of the stomach is seen in the centre, arranged in vertical plaits or folds.

22. CARYOPHYLLIA, AND TURBINOLIA.—In this small recent coral (*Turbinolia ruber*) we have an example of a single calcareous cell, divided by vertical lamellæ or partitions, arranged in a radiated manner. This cell is the skeleton or stony support of a single polype, having a double row of tubular tentacula, and bearing a great analogy to the Actinia ; indeed, the recent animal may be described as an Actinia with a calcareous skeleton, fixed by its base. The fossil *Turbinolia* (*ante*, p. 320, *figs.* 1, 2), and *Caryophyllia* (*fig.* 3.), possess a similar structure. A beautiful living Turbinolia, which is marked with red and white bands, is shown in *Pl.* VI. *fig.* 8 : and a similar coral with its tentacula expanded, in *fig.* 14.

* By Dr. Robert B. Todd ; Cyclopædia of Anatomy and Physiology, p. 614.

In the *Caryophyllia* possessing more than one cell, each cell contains an actiniform polype: one of those of *C. fasciculata*, which is of a bright green colour, is represented *Pl.* V. *fig.* 4. In another genus, *Pocillopora*, the investing fleshy integument is beautifully mottled, and the polypes, which are of a blue colour, are terminal, as in the Caryophyllia. A branch, as seen alive in the water, is figured in *Pl.* V. *fig.* 11.

23. Fungia.—The white, disciform, lamellated corals, called Sea-mushrooms, or *Fungia*, from their fancied resemblance to fungi, are among the most elegant and abundant forms of polyparia in the cabinets of collectors. These, in a living state, are covered with a thick, transparent, jelly-like substance, which fills up all the numerous radiating interstices of the calcareous laminæ; in the central depression of the fleshy mass is situated a large polype with tentacula; in the Fungia, there is but one polype—but one focus of vitality. In the *Fungia actiniformis* (*Pl.* VI. *fig.* 15), the polype strikingly resembles the Actinia; the whole surface of the disk is covered with long, tubular, conical, prehensile tentacula, with minute terminal apertures, and striated, transverse, muscular bands; these tentacula are protruded by the injection of water from below, as in the Actinia. In the Fungia the stony base is secreted from the inferior surface of the soft substance, and is attached or cemented, as it were, to the rock.

24. Astræa, Pavonia, &c.—In some of the large stony corals, the cells of the polypes are very numerous, and the coralline mass presents a surface beautifully marked with stellular impressions. The *Astræa viridis* is here represented as seen alive in the sea (*Pl.* VI. *fig.* 13). The polypes in this coral are of a dark-green colour, six lines in length, and are protected by deep, laminated, polygonal cells, two lines in diameter. They are striated with longitudinal and transverse bands, and connected by a fleshy

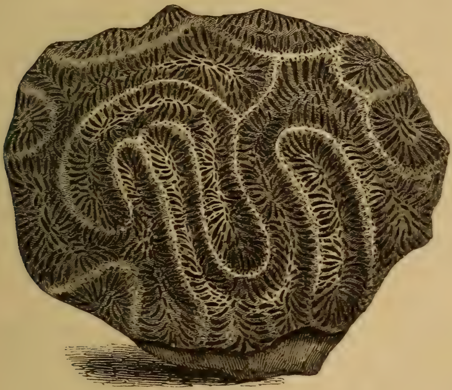
layer which covers the dark brown coral; some of the polypes are here shown expanded, and others contracted. In this magnified view (*Pl.* VI. *fig.* 10) of a single polype, the tentacula are seen expanded, or disposed around the prominent mouth. The appearance of groups of Astreæ, and other corals, when viewed while the animals are alive and in activity, is most beautiful; looking down through the clear sea-water, the surface of the rock appears one living mass, and the congregated polypes present the most diversified and vivid hues.

The *Pavonia* are those corals which have deep and isolated cells, each containing a large depressed polype, very similar in its appearance and structure to the Actinia. *Pl.* VI. *fig.* 11, represents a group of cells containing polypes, of the *P. lactuca*, from the shores of the South Sea islands. The polypes are of a green colour, and there is a connecting, transparent, fleshy substance, which extends over the extreme edges of the foliated expansion of this elegant zoophyte.

From the magnitude and muscularity of the polypes in these large lithophytes, and the increased number and strength of their prehensile organs, they are capable of seizing and digesting more highly organized prey, than the delicate, minute, cellular zoophytes.

25. Meandrina cerebriformis; or *Brain-coral.*—The large hemispherical corals, having the surface covered with meandering ridges and depressions, disposed in a manner somewhat resembling the convolutions of the brain, are well known by the name of *Brain-stone* (*Lign.* 138). In a living state the mass is invested with a fleshy substance, variously coloured, and having numerous, short, conical, polypiform, confluent cells, arranged in rows between the ridges. This zoophyte sometimes attains considerable magnitude; a very beautiful specimen in the British Museum is four feet in circumference. The base of the Meandrina,

like that of the Fungia, is adherent to the rock, with which, being formed of a like material, it becomes identical. As



LIGN. 138.—BRAIN-STONE CORAL.

(*Meandrina cerebriformis.*)

one fleshy mass expires, another appears, and gradually expands, pouring out its calcareous secretion on the parent mass of coral; thus successive generations go on accumulating vast beds of stony matter, and laying the foundations of coral reefs and islands. We may compare, observes Mr. Lyell,* the operation of the zoophytes in the ocean, to the effects produced on a smaller scale on land, by the plants which generate peat; in which the upper part of the Sphagnum, or peat-moss, vegetates, while the lower is entering into a mineral mass, in which the traces of organization remain when life has entirely ceased. In these Corals, in like manner, the more durable materials of the generation that has passed away, serve as the foundation over which

* Principles of Geology.

their progeny spreads successive accumulations of calcareous matter.

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

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

The impressions produced upon first seeing a grove of live corals, are thus vividly portrayed by Mr. Jukes:*—

"In a small bight of the inner edge of the coral reef, was a sheltered nook, where the extreme slope was well exposed, and where every coral was in full life and luxuriance. Smooth round masses of meandrinæ and astreæ were contrasted with delicate, leaf-like, and cup-shaped expansions of explanariæ, and with an infinite variety of branching madreporæ, some with mere finger-shaped projections, others with

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* "Narrative of the Surveying Voyage of H. M. S. *Fly*, in 1842—1846;" by J. B. Jukes, Esq., Naturalist of the Expedition.

large branching stems, and others again exhibiting an elegant assemblage of interlacing twigs, of the most delicate and exquisite workmanship. Their colours were unrivalled: vivid greens, contrasting with more sober browns and yellows, mixed with rich shades of purple, from pale pink to deep blue. Bright red, yellow, and peach-coloured millepores clothed those fleshy masses that were dead, mingled with beautiful pearly flakes of escharæ and reteporæ; the latter looking like lace-work in ivory. Amidst the branches of the corals, like birds among trees, floated many beautiful fish, radiant with metallic greens or crimsons, or fantastically banded with black and yellow stripes. Patches of clear white sand were seen here and there on the floor, with dark hollows and recesses, beneath overhanging masses and ledges. All these, seen through the clear crystal water, the ripple of which gave motion and quick play of light and shadow to the whole, formed a scene of the rarest beauty, and left nothing to be desired by the eye, either in elegance of form, or brilliancy and harmony of colouring."

27. Coral reefs.—The vast accumulations of calcareous rocks in tropical seas, resulting from the consolidation of the disintegrated skeletons of polyparia, have already been alluded to, but the physical changes that are produced by such apparently inadequate means require further consideration, since they illustrate the formation of the coralline rocks of the secondary and palæozoic epochs.

In the *Flustra foliacea* of our coast (*ante*, p. 608), delicate and brittle though it be, we perceive the elements of those important changes to which the large lamellar corals of tropical seas are giving rise. In the specimen before us, you may observe that the base of the mass of Flustra, which is about six inches in diameter, is already consolidated by an aggregation of sand, that has filled up the interstices. On the surface are numerous parasitical shells and corals, and between the convolutions of its foliated expansions, echini, crustacea, and other animals, have taken shelter; while sand and mud have invested every cranny of the lower third of the specimen, and imbedded serpulæ, sabellæ, and fragments of many species of shells. It is evident, that were the whole specimen filled up and surrounded by detritus, as it shortly would be at the bottom of the sea, a solid block would be formed, exhibiting, when broken, the remains of the Flustra, impacted in a conglomerate of sand, shells, and corals. Thus we perceive that even the delicate, friable, skeletons of the Flustræ of our shores, may become the nucleus of a solid rock; and in the process described, we have, as it were in miniature, the formation of a coral reef.

28. CORAL REEF OF LOO CHOO.—But it is in tropical seas that the *Meandrinæ*, *Astrææ*, *Caryophylliæ*, and other stony corals, form those immense masses, which not only give rise to groups of islands in the bosom of the ocean, but are gradually forming tracts of such extent, that a new continent may spring up where the fabled Atalantis is supposed to have once flourished. From the many interesting descriptions of the nature and formation of Coral reefs and Islands, that have been published by our voyagers, I select the following graphic account, by Captain Basil Hall, of a coral reef near the great island of Loo Choo:—

"When the tide has left the rock for some time dry, it appears to be a compact mass, exceedingly hard and rugged: but as the water rises, and the waves begin to wash over it, the polypes protrude themselves from holes which were before invisible. These animals are of a great variety of shapes and sizes, and in such prodigious numbers, that in a short time the whole surface of the rock appears to be alive and in motion. The most common form is that of a star, with arms, or tentacula, which are moved about with a rapid motion in all directions, probably to catch food. Others are so sluggish that they may be mistaken for pieces of the rock, and are generally of a dark colour. When the coral is broken above high-water mark, it is a solid, hard stone; but if any part of it be detached at a spot where the tide reaches every day, it is found to be full of polypes of different lengths and colours; some being as fine as a thread, of a bright yellow, and sometimes of a blue colour. The growth of coral appears to cease when no longer exposed to the washing of the sea. Thus a reef rises in the form of a cauliflower, till the top has gained the level of the highest tides, above which the animalcules have no power to advance, and the reef of course no longer extends upwards."

29. Coral islands.—Kotzebue, Flinders, MM. Quoi and Gaimard, Mr. Darwin, and others, have severally described the formation of Coral islands; the following is an abstract of their observations.

The Coral banks are every where seen in different stages of progress: some are become islands, but not yet habitable; others are above high-water mark, but destitute of vegetation; while many are overflowed with every returning tide. When the polypes of the corals at the bottom of the ocean cease to live, their skeletons still adhere to each other, and the interstices being gradually filled up with sand and broken pieces of corals and shells, washed in by the sea, a mass of rock is at length formed. Future races of these animalcules spread out upon the rising bank, and in their turn die, and thus increase and elevate this wonderful monument of their existence.

The reefs which raise themselves above the level of the sea, are usually of a circular or oval form, and surrounded by a deep and oftentimes unfathomable ocean. In the centre of each, there is generally a shallow lagoon with still water, where the smaller and more delicate kinds of zoophytes find a tranquil abode; while the stronger species live on the outer margin of the isle, where the surf dashes over them. When the reef is dry at low water, the coral animals cease to increase. A continuous mass of solid stone is then seen, composed of shells, echinoderms, and fragments of corals, united by calcareous sand, produced by the pulverization of the shells and of the friable polyparia. Fragments of coral limestone are thrown up by the waves; these are cracked by the heat of the sun, washed to pieces by the surge, and drifted on the reef. After this the calcareous mass is undisturbed, and offers to the seeds of the cocoa, pandanus, and other trees and plants, floated thither by the waves, a soil on which they rapidly grow, and overshadow the white, dazzling surface. Trunks of trees, drifted by currents from other countries, find here at length a resting-place, and bring with them some small animals, as lizards, insects, &c. Even before the trees form groves or forests, sea-birds nestle there, and strayed land-birds find refuge; and at a still later period, Man takes possession of the newly-created country. It is in this manner that the Polynesian Archipelago has been formed.

The immediate foundations of these islands are ancient coral reefs, and some of these, in all probability, are based on the cones or craters of submarine volcanoes long since extinct; and others on the lofty peaks of a submerged continent which has undergone a slow subsidence, and thus admitted of the growth of successive generations of the coral-secreting zoophytes, and the formation of immense beds and zones of submarine coralline rocks. There is another circumstance worthy of remark: most of these islands have an inlet through the reef opposite to the large valleys of the neighbouring land, whence numerous streams issue and flow into the sea; an easy ingress is thus afforded to vessels, as well as the means of obtaining an abundant supply of fresh water.

Of the immense extent of the changes here contemplated, we may form some idea from the facts stated by competent observers, that in the Indian Ocean, to the south-west of Malabar, there is a chain of reefs and islets 480 geographical miles in length; on the east coast of New Holland, an unbroken reef 350 miles long; between that and New Guinea, a coral formation which extends upwards of 700 miles; and that Disappointment Islands and Duff's Group are connected by 600 miles of coral reefs, over which the natives can travel from one island to another.

30. Formation of Coral Islands.—From the grand scale on which these operations have been carried on in the Pacific, and the powerful volcanic action of which those latitudes have been the theatre, as shown by the elevatory movements to which the neighbouring continents have been subjected, the extremely small extent of dry land in that world of waters is a very striking phenomenon. This remarkable fact was supposed by Mr. Lyell* to admit of explanation, on the supposition that a gradual subsidence had been going on for ages over a vast area of the bed of the Pacific, which occasioned the solid materials produced by the coral zoophytes, to sink down beneath the waters, and therefore no considerable additions were made to the dry land above the level of the sea: the Polynesian Archipelago, and the submerged coral reefs, alone indicating the stupendous changes effected by zoophytal agency. This opinion has been confirmed by the observations of Mr. Darwin, whose explanation of the mode in which the formation of Coral Islands takes place, is a beautiful example of philosophical induction.

The coral reefs are described by Mr. Darwin as of three distinct kinds, arising from the different circumstances attending their production. First, *Atolls*;† secondly, *barrier reefs*, which are ridges of coral either extending in straight lines in front of the shores of a continent or large island, or encircling a group of small islands, and separated from the land by a deep channel of water; thirdly, *fringing reefs*, or banks of coral, superimposed on the slopes of the adjacent land, and at no great distance from the shore.

By the gradual subsidence of the land, and the coincident upward growth of the corals, fringing reefs are gradually converted into barrier reefs, and the latter into Atolls. Hence it is inferred, that coasts merely fringed by reefs

* Principles of Geology, 1st edition.

† An Indian name for the circular or lagoon islands.

have not subsided to any considerable amount, but either have remained stationary, or been upheaved since the growth of the coral. When a barrier reef, encircling an island, gradually sinks down, the corals go on growing vigorously upwards ; but, as the island sinks, the water gains inch by inch on the shore, and the mountain-tops at length become separate islands, within one great reef; and ultimately the highest pinnacle disappears, and a perfect Atoll is formed. Hence lagoon islands, having originated from encircling barrier reefs, resemble them in general size and form, and in the manner in which they are grouped together ; and they may be regarded as outline charts or models of the sunken islands they now surmount. By this theory of the upward growth of polyparia during the subsidence of the land on which they are based, Mr. Darwin satisfactorily explains all the leading phenomena of those marvellous structures, the barrier reefs; and of those fairy coral islands that begem the vast expanse of the Pacific, and flourish in the midst of its mighty billows. The narrow belt of land of these insular zones, frequently but a few hundred yards wide, is surrounded by a deep and often unfathomable ocean, and encloses a lake of tranquil water ; it is crowned with cocoa-nut trees, clothed with a luxuriant tropical vegetation, and begirt with a beach of glittering sand, on which are constantly dashing the snow-white breakers of the azure sea. Nowhere, as Mr. Darwin beautifully remarks, can be found such wonderful proofs of the power of vitality to repel the influence of mechanical force ; for the breakers far exceed in violence those of our temperate regions, and it is impossible to behold them without feeling a conviction, that rocks of quartz or granite would speedily be demolished by such irresistible agents ;* and yet there stand, immoveable, those marvellous monuments—

* See Mr. Darwin's delightful volume, "On the Structure and Distribution of Coral Reefs."

"Raised by the feeblest creatures in existence,"

unscathed by the raging billows, and smiling with perpetual verdure—the oases of that vast wilderness of waters!

31. Montgomery on Coral Islands.—The formation of islands and continents by the vital energies of countless myriads of minute beings, the unconscious living instruments of stupendous physical changes, is invested with so much of the sublime and the marvellous, as to form a subject alike calculated to engage the attention of the philosopher, and to excite the imagination of the poet; and I am tempted to relieve this detail with the following beautiful lines by James Montgomery:*—

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

* From "The Pelican Island," by James Montgomery.

What are the works of intellectual man,
His temples, palaces, and sepulchres?
Dust in the balance, atoms in the gale,
Compared with these achievements in the deep,
Were all the monuments of olden time!
Egypt's grey piles of hieroglyphic grandeur,
That have survived the language which they speak,
Preserving its dead emblems to the eye,
Yet hiding from the mind what these reveal;
Her Pyramids would be mere pinnacles,
Her giant statues, wrought from rocks of granite,
But puny ornaments for such a pile,
As this stupendous mound of catacombs,
Fill'd with dry mummies of the builders, worms!"

32. Fossil Zoophytes.—The conditions under which corals and other zoophytes are preserved in the mineral kingdom, and the formation of conglomerates from the debris of corals and shells, have been described in the previous lectures; in this place I shall offer a cursory review of the geological distribution of fossil zoophytes, without entering upon details which will be found more or less fully exemplified, in the account of the organic remains of the respective systems of deposits.

The coralline limestones now forming on the shores of the Bermuda Islands (*ante*, p. 85), and conglomerates on those of the Isle of Ascension (p. 90), prove that at the present time accumulations of calcareous stone are going on, similar in character to many of the fossiliferous deposits of the Chalk, Oolite, and other ancient formations. Mr. Darwin has observed a similar effect in the Pacific, where disintegrated coral reefs give rise to vast deposits of calcareous detritus, which, when dry, closely resembles soft chalk. In the West Indies, blocks of silicified meandrinæ, astrææ, and other reef-forming species, are abundantly distributed in the superficial alluvium of Antigua and other islands. The pliocene, or newer tertiary, of Palermo, abounds in corals of species that still inhabit the Mediterranean. In the Crag, there are numerous existing species of corals, with many extinct, or unknown as natives of the adjacent seas. The miocene of North America contain many kinds of polyparia, some of which appear to be peculiar to those strata.* In the eocene deposits there are several extinct genera and many species, associated with some living forms. In the Chalk formation corals are locally abundant, in the sandy and argillaceous strata (as at Maestricht); but throughout vast areas of the fine white chalk, there are no considerable beds of corals, nor appearance of coral reefs: the species are, for the most part, small and delicate (*ante*, p. 319).

The manner in which the remains of polyparia are distributed in the white chalk involves an interesting inquiry; they occur promiscuously intermingled with shells, echini, and fishes; we find no beds of corals—nothing to point out the former existence of reefs. This phenomenon, however, is in accordance with the general lithological character of the Chalk formation, and the nature of its organic remains; both of which indicate a profound ocean. As polyparia can only exist at moderate depths, the occurrence of coral reefs was not to be expected, except in those areas which may be supposed to have been formed in the shallows, or near the sea-shores.

In the Danish islands of Seeland and Möen, the flinty chalk is covered by coral limestone, some portions of which form a compact building-stone, while others are mere masses of coral cemented together by a white detritus. These beds belong to the chalk formation, for although they abound in univalve shells not common in our cretaceous strata, yet a large proportion of the sponges, corals, echinites, and belemnites, are identical with those of the English Chalk. Mr. Lyell therefore infers, "that the peculiarity of the fossil

* See report on Corals from the Tertiary Formations of North America, by Mr. Lonsdale; Geol. Journal, vol. i. p. 495.

fauna of Faxoe* was produced more by geographical conditions, such, for example, as the local shallowness of that part of the cretaceous sea, than by any general change in the creatures inhabiting the ocean, effected in the period that may have intervened between the formation of the white chalk and the Faxoe limestone."

The remains of sponges are very frequent in the flinty chalk, and in many places not only do they swarm in the limestone, but also in the flints; so that almost every nodule

LIGN. 139.—FOSSIL PORIFEROUS ZOOPHYTES; FROM FARINGDON, BERKS.

(Collected and drawn by Miss Ellen Maria Mantell.)

Fig. 1. *Tragos peziza.* 3. *Verticillipora anastomosans.*
2 and 4. *Scyphia.* 5. *Tragos?*

encloses a sponge or other poriferous zoophyte. The greensand in some localities contains immense numbers of poriferæ.

* A locality in Denmark, where these deposits are best displayed. See Geol. Trans. vol. v. new series.

The gravel pits, as they are called, in the neighbourhood of Faringdon, in Berkshire, are extremely prolific in fossils of this kind. These beds consist of a coarse friable conglomerate, formed of sand, shells, corals, echinoderms, and the debris of other marine animals, impregnated with iron; some layers of concretionary indurated masses occur, originating from infiltration of carbonate of lime.

They contain myriads of perfect shells and poriferæ; casts of nautili and ammonites; waterworn oolitic belemnites,

LIGN. 140.—FOSSIL ZOOPHYTE FROM FARINGDON.

(Chenendopora fungiformis.)

and shells; teeth of fishes, &c. In a few visits to these quarries I collected numerous specimens of nautili, belemnites, ammonites, ostreæ, terebratulæ, and echinites and their spines; milleporæ, tubiporæ, and several minute corallines, with many varieties of the Spongiadæ (see *Lign.* 139), and some zoophytes whose affinities have not yet been determined. The *Verticillipora anastomosans* (*Lign.* 139, *fig.* 3) is a very elegant coral, often met with in this locality.

One of the most abundant and perfect of the Poriferæ, is a cyathiform zoophyte (*Lign.* 140), called by the quarrymen "*Petrified salt-cellar;*" it is of a porous structure, and the inner surface is covered with oscula, or little openings.

33. VENTRICULITES OF THE CHALK.—A very elegant and interesting family of Zoophytes, described by me in an early memoir (published in the "Linnæan Transactions," Vol. xi.), and subsequently named *Ventriculites*, occurs in the Sussex and Wiltshire chalk in such numbers, and under such dissimilar forms, as to require a passing notice in this place; especially as the subject has recently been investigated by a gentleman of distinguished ability.* After mature reflection, and the re-examination of such specimens as are within my reach, I see no reason whatever to alter a single word in the following description, taken from my late work on fossil remains.†

"The original form of the Ventriculite was that of a funnel, or hollow inverted cone, terminating in a point at the base, whence numerous fibres proceed, by which it was attached to other bodies. The outer integument was reticulated—that is, disposed in meshes like net-work, and the inner surface was studded over with regular openings; the orifices of tubular cells, each of which was probably occupied by a polype. The substance of the polyparium, or frame-work, of this aggregation of animalcules, appears to have been analogous to that of the soft alcyonia, and to have possessed a common irritability,

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* On the Ventriculidæ of the Chalk, by J. Toulmin Smith, Esq.—*Ann. Nat. Hist.* No. 131, p. 73.

I cannot admit the correctness of Mr. Toulmin Smith's interpretation of the appearances described in the text; of the accuracy of his beautiful microscopic examination of the intimate tissue of these zoophytes I have no doubt; and will only remark, that the octahedral form, represented as that assumed by the inosculating fibres of the membrane of the Ventriculidæ (Ann. Nat. Hist. pl. vii. fig. 8), is a very extraordinary anomaly in animal structures.

† Medals of Creation, vol. i. p. 274. The figures in *Lign.* 60, 61, and 62, of that work, though on a small scale, are accurate representations of the originals.

and been able to expand and contract.* This opinion is based on the circumstance, that some specimens occur in which the zoophyte is in the form of a nearly flat circular disk, and others in that of a sub-cylindrical pouch; in the former state, the outer reticulated structure is elongated, while in the latter, it is contracted and corrugated. The polype-cells are cylindrical and very regular; the flints often present beautiful casts of them, which appear like rows of minute pillars on the inner surface." †

When the flint that fills up the cavity of a Ventriculite can be extracted, it is a solid cone, having its surface studded over with papillæ, which are casts of the orifices of the polype-cells. When the enclosed polyparia in flint nodules have perished, chalcedony, and quartz crystals, and sometimes crystallized pyrites, are found filling up, more or less completely, the cavities left by the decayed parts of the zoophyte.‡

34. Zoophytes of the Jurassic formation.—The Oolite, as we have previously remarked, abounds in corals, and contains beds of limestone which are merely coral-reefs that have undergone no change but that of elevation from the bottom of the deep, and the consolidation of their materials. The Coral-rag, in fact, presents all the characters of modern reefs; the polyparia belong to *Astrææ*, *Caryophylliæ*, *Madreporæ*, *Meandrinæ*, and other genera which principally contribute to the formations now going on in the Pacific. Shells, echini, teeth and bones of fishes, and other marine exuviæ, occupy the interstices between the corals, and the whole is consolidated by sand and gravel, held together in some instances by calcareous, in

* As in the Flustræ and Pennatulæ previously described (*ante*, p. 610).

† See Op. cit. pp. 269—278.

‡ I beg to refer to my paper on a "Microscopic Examination of Chalk and Flint," published in Ann. Nat. Hist. 1845; and "Geological Excursions round the Isle of Wight," pp. 179—184, for a particular account of the silicification of these and other zoophytes.

others by siliceous infiltrations.* Large masses of a cellular coral (*Eunomia radiata*) abound in the limestones of the Great Oolite. The corals, shells, &c. are for the most part of extinct species and genera. Those who have visited districts where the Coral-rag forms the immediate sub-soil, and is exposed to view in the quarries, or in natural sections, must have been struck with the resemblance of these rocks to modern coral-banks. We know that in our present seas all situations and circumstances are not alike favourable to the existence and growth of polyparia; in some parts of the ocean they abound, and in others are altogether wanting. In like manner in the deposits of the Jurassic formation, which extend over a great part of Europe, and have been formed in a sea of vast extent, beds of coral are not universally distributed, but occur only in certain districts; in other words, they occupy the situations which in their native seas presented the conditions required by their peculiar organization.

The Lias contains comparatively but few polyparia; and the Trias only a small number, including three or four species of Gorgonia, three of Retepora, and one of Astræa.

35. CORALS OF THE PALÆOZOIC FORMATIONS.—The Mountain limestone of the carboniferous system, which will come under our notice in the next discourse, abounds in the cellular, and lamelliferous zoophytes: and many of the deposits of the Devonian and Silurian systems, teem with anthozoan corals; for the most part of peculiar forms, and typical of particular groups of strata. The corals of the Silurian deposits of England,† equally prevail in the corresponding strata of North America.‡

* In the chert of the Portland oolite of Tisbury, Wiltshire, masses of a beautiful silicified coral occur; a fragment of a polished section is shown in *Lign.* 141, *fig.* 9.

† Sir R. I. Murchison's "Silurian System," vol. ii.

‡ See Professor Hitchcock's "Geology of Massachusetts," and Professor Hall's "Geology of the State of New York."

This wide geographical range of the same types of coralline zoophytes, seems to indicate a more equal temperature

LIGN. 141.—FOSSIL CORALS.

Fig. 1, 3. Cyathophyllum turbinatum; Wenlock limestone, Dudley.
— 2. Fungia lenticulata; Dudley.
— 4. Surface of Astræa ananas; Devonshire.
— 5. Syringopora geniculata; Mountain limestone; Mendip Hills.
— 6. Caryophyllia annularis; Coral-rag; Wilts.
— 7. Millepora; Coral-rag; Faringdon.
— 8. Lithostrotion striatum; Mountain limestone; Yorkshire.
— 9. Surface of Astræa Tisburiensis; Portland Oolite; Wilts.
— 10. Coralline Marble; Devonshire.

in the seas of those remote epochs than at present prevails; for the reef-forming genera do not now exist in waters of a temperature under 70°, and are therefore, with the exception of the Bermudas (*ante*, p. 614), restricted to intertropical regions.*

The simple turbinated corals, consisting, like the Fungia (*Pl.* VI. *fig.* 8), of a solitary cell (*Lign.* 141, *fig.* 1. 3), are found in great abundance and perfection in the Silurian limestones of Dudley, Wenlock, &c.; and are associated with numerous large stony corals, and the elegant branched Cyathophylla, Tubiporidæ,† &c. Of the latter, the Wenlock limestone (in North America, as well as in England), contains a genus of singular beauty, and which, from the appearance presented by cross sections, is known by the name of *Chain-coral* (*Catenipora escharoides; Lign.* 143, *fig.* 3). The tubes of this coral being oval, and arranged perpendicularly side by side in undulating lines, display in the transverse sections elegant markings resembling the anastomosings of delicate chains.

The fossil branched polyparia, termed Lithodendron,‡ form continuous layers, or reefs, in the mountain limestone of Ireland; and on the weathered surface of the stone, the corals stand out in relief, as sharp as in the rocks of a recent lagoon.

The Syringoporæ,§ which consist of clusters of parallel tubes, laterally united like the recent Tubipore (*Pl.* V. *fig.* 9), prevail in many of the beds of mountain limestone, and give rise to elegantly figured marbles (*Lign.* 143, *fig.* 2).

36. CORALLINE MARBLES.—Certain limestones, largely composed of corals, in which the interstices have been filled up by calcareous spar, and the inclosed zoophytes

* See "Medals of Creation" for figures and descriptions of numerous fossil corals, vol. i. chap. viii.

† See the exquisite lithographs, by Mr. Scharf, in Sir R. I. Murchison's "Silurian System."

‡ "Medals of Creation," *Lign.* 55, pp. 257, 303.

§ Ibid. p. 297.

more or less transmuted into the same substance, are susceptible of a high polish, and constitute some of the most beautiful marbles. The limestones of Babbicombe, and Torquay, in Devonshire, and those of Clifton, owe their markings to the petrified zoophytes of which they are in a great measure made up. The black Kilkenny marble is mottled with varied and elegant figures of the purest white, which are sections of corals and shells transmuted into calcareous spar.

LIGN. 142.—FAVOSITES POLYMORPHA; A SECTION OF A POLISHED PEBBLE, FROM TORQUAY.
(Drawn by Miss Jane Allnutt.)*

Many of the pebbles thrown up by the waves on the shore along the coast of Devonshire, are water-worn fragments of the coralline limestones of that country, and when cut and polished, display exquisite sections of the enclosed corals (*Lign.* 143).†

* From a beautiful specimen in the possession of Mrs. Allnutt, of Clapham Park.

† The form and structure of the species of coral, of which a section appears in this polished pebble, are shown in *Lign.* 66, Medals of Creation, vol. i. p. 295.

A reddish marble, beautifully marked by the sections of the enclosed Tubipores, and susceptible of a good polish, is quarried in some parts of Derbyshire (*Lign.* 143, *fig.* 2). Mr. Parkinson ascertained that the hue of this marble is dependent on the original colour of the coral, which, probably, like the recent tubipore (*ante*, p. 619), was of a rich scarlet hue.

1. 2.

3.

LIGN. 143.—CORALLINE MARBLES.

Fig. 1. Silurian limestone, composed of a species of Syringopora; Dudley.
— 2. Polished section of a marble formed of *Syringopora strues*; Derbyshire.
— 3. Chain-Coral (*Catenipora escharoides*); Dudley.

I have mentioned (*ante*, p. 609), that the earthy matter of the recent corals, like the phosphate of lime in the bones of animals, is secreted by a membranous structure, and that if the lime be removed by a chemical process, the tissue will be rendered manifest. Few, however, will be prepared to learn, that even in corals which have been entombed in the solid rock for innumerable ages, the animal membrane can be detected. To my late friend, Mr. Parkinson, we are indebted for the knowledge of this interesting fact. He immersed a piece of marble (*Lign.* 143, *fig.* 2) in dilute muriatic acid, which has the property of dissolving calcareous earth, but cannot affect animal matter: to employ his own words, "as the calcareous earth dissolved, and the carbonic acid gas escaped, I was delighted to observe the membranous substance depending from the marble in light flocculi, of a deep red colour; and although not retaining the tubular form of the original coral, yet appearing in a beautiful and distinct manner."*

37. Crinoidea, or Lily-shaped animals.† — The Echinites, so numerous in the chalk (*ante*, p. 327), and the Star-fishes, which are more sparingly distributed in the cretaceous strata (*ante*, p. 327), are referable to the same group of marine animals as those to which I would now direct your attention. All these creatures belong to the class *Radiaria*, so named from the different parts of which they are composed being arranged symmetrically around one common centre. This structure is exemplified in the *Asterias*, or Star-fish, that abounds on our coasts, and must be familiar to every one. This animal has a central disk containing the mouth and viscera, from which proceed five long arms, or rays; the skeleton is composed of numerous little bones, enveloped in a tough integument. These bones, or *ossicula*, are calcareous; and are in close apposition over the body, but are articu-

* Organic Remains of a Former World, vol. ii. p. 181. *Pl.* I. *fig.* 3.

† Medals of Creation, chap. ix.

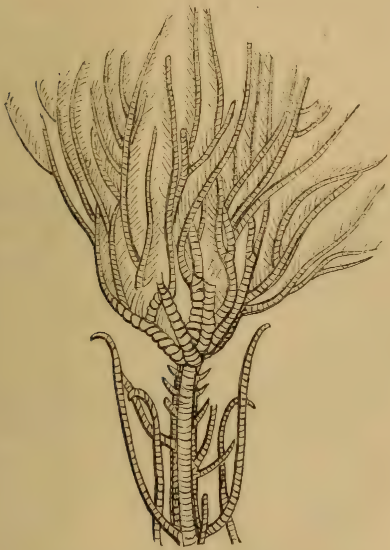
lated together in regular series along the margins of the rays, which are therefore strong and flexible. A longitudinal furrow extends from the mouth to the extremity of each ray, the sides of which are perforated by alternating rows of pores, for the exsertion of tubular tentacula.

Some kinds of Star-fish (the *Comatulæ*, or Feather Stars), instead of the five flat rays, have jointed arms, that proceed from a central cup-shaped calcareous base, and divide, and subdivide into delicate jointed tentacula, the sides of which are fringed with rows of still smaller articulated pinnæ, or processes.* Now, if we imagine a Comatula placed with its mouth upwards, and fixed on the top of a jointed stem by the centre of its dorsal surface, we have the essential type of the Crinoideans, or Lily-shaped animals, so named from a fancied resemblance of some of the species when in a state of repose to a closed lily. The only known living genus of this family inhabits the seas around the West Indies; and of this sole representative of the numerous crinoideans of the palæozoic ages, but five or six specimens have been brought to Europe. It belongs to that subdivision in which the joints of the column are pentagonal, and is therefore named *Pentacrinus*.

38. Structure of the Crinoidea.—From this recent example (*Lign.* 144), which does not essentially differ from the extinct forms, an accurate knowledge of the structure of these curious animals has been obtained. The Crinoideans are characterized by having a root or process of attachment, by which they are fixed at the base to the rock; a stem composed of numerous articulations, or separate pieces of a solid calcareous substance; and a cup or vase at the summit of the stem, which contains the body or viscera of the animal, and from the upper border of which

* The living British Star-fishes are beautifully figured in Professor E. Forbes's charming work, published by Van Voorst, 1841.

proceed articulated arms or tentacula. When the animal is alive, the skeleton is covered by a soft integument, as in the Star-fishes; the mouth is situated on one side of the centre of the receptacle, which is surrounded by the arms

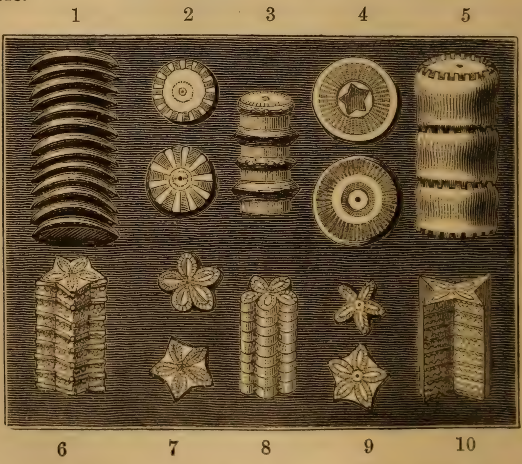


LIGN. 144.—THE BODY, AND UPPER PART OF THE STEM OF A PENTACRINUS.

(From the West Indian Seas.)

that spread out and expand into a net to capture the living prey, and, like the tentacula of the hydra, seize and convey it to the mouth. I scarcely need remark that the Crinoidea are individual organisms, and are never aggregated and united by one common axis, as are the compound Polyparia that lately engaged our attention. There are some fossil crinoideans destitute of a stem, and these must have been free animals, floating at liberty through the water, like the recent Feather-stars.

The number of ossicula in the skeleton of a single encrinite is computed at thirty thousand; but in the more complicated Pentacrinites they exceed one hundred and fifty thousand, and in the plumose Encrinites must amount to hundreds of thousands. The detached ossicula occur in myriads in the Mountain limestone and Silurian rocks, and the relics of one species alone forms thick beds of marble.



LIGN 145.—STEMS OF ENCRINITES AND PENTACRINITES.

Fig. 1. Screw, or Pulley-stone; a cast in the hollow of an encrinital column.
2, 4. Articulating surfaces of different kinds of encrinital ossicula.
3, 5. Portions of encrinital stems, or Entrochi. 6, 8, 10. Stems of Pentacrinites.
7, 9. Separate ossicula of Pentacrinites.

39. ENCRINITES AND PENTACRINITES.—The fossil remains of Crinoidea consist of the ossicula of the column, arms, and tentacula; of the plates of the vase or receptacle;

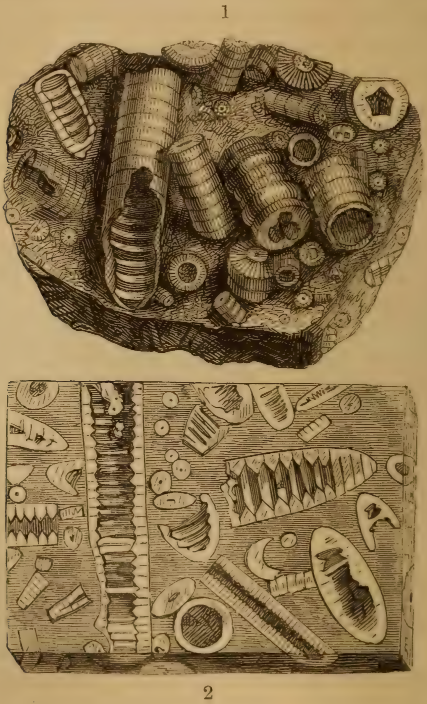
and of the peduncle or process of attachment, by which the base of the column was permanently fixed to the rock. The separate bones of the column were called *trochites*, or wheel-stones, by the early collectors; and several united, *entrochites*. In the north of England they were popularly known by the name of *fairy-stones*, and St. Cuthbert's beads: the circular perforated kinds are occasionally found in tumuli, having been worn as ornaments by the ancient Britons. These bodies present considerable variety in form, and their articulating surfaces are marked with diversified floriform and stellular figures; as in the series of specimens before us (*Lign.* 145). The central perforation, which is circular and very small in some species, and large and pentagonal in others, forms in the united column a channel from the receptacle to the base, which is supposed to have contained a chord of nervine or medullary matter. The inner part of the ossicula seems to have been more perishable than the external zone; for the latter is often filled up either with spar, or the material of the surrounding rocks. In the siliceous veins and bands of chert that pervade some of the limestones of Derbyshire, the curious fossils termed pulley-stones often occur; these are casts formed by the infiltration of silex into the cavities of encrinital columns (*Lign.* 145, *fig.* 1).

The skeletons of the Crinoidea, like the stony fabric of the corals, were, of course, secreted by the animal membrane; and, as in the fossil tubipore (*ante*, p. 645), this tissue may be detected. Upon submitting some encrinital ossicula from the Derbyshire limestones to the action of weak acid, the calcareous earth was removed, and the original membrane appeared in transparent flocculi.*

40. Derbyshire encrinital marble.—Some of the

* See Parkinson's Organic Remains, vol. ii. p. 166.

strata of mountain limestone consist entirely of remains of Crinoidea, principally of one species of the Encrinites, or cylindrical stems; and in Derbyshire some of the beds form



LIGN. 146.—ENCRINITAL MARBLE OF DERBYSHIRE.

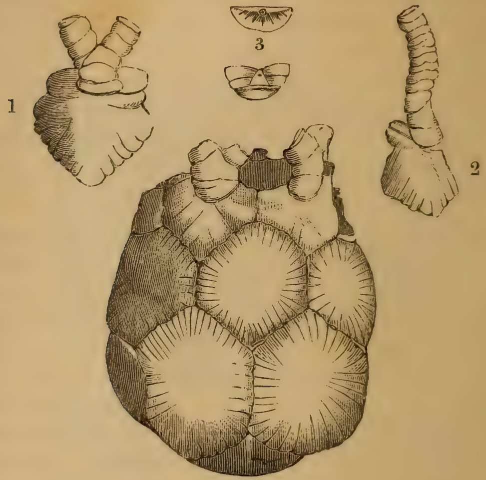
Fig. 1. Entrochites, or fragments of stems of Encrinites, lying in relief on a block of limestone.
2. Polished slab of Derbyshire encrinital marble.

a compact marble (*Lign.* 146), which is largely employed for chimney-pieces and other ornamental purposes.

In the quarries on Middleton Moor, a short distance from Cromford, in Derbyshire, extensive quarries of this marble are worked, and abundance of these fossils are everywhere scattered about. The cavities of the entrochites are often filled with white calcareous spar, while the ground of the marble is of a dark reddish brown. In other varieties the substance of the fossils is white and the ground dark grey or brown: both kinds when worked into polished slabs or ornaments, are very beautiful and interesting. A specimen of the limestone with the crinoideal columns in relief, is represented *Lign.* 146, *fig.* 1; and a polished slab in fig. 2.

41. THE LILY ENCRINITE.—One of the most elegant of the fossil crinoidea is the *Lily Encrinite*, which, as already stated, occurs only in the Muschelkalk of the Triassic system of Germany (*ante*, p. 549), and is principally found in one locality, near the village of Erkerode, in Brunswick. The structure of this zoophyte is beautifully exemplified in the fine specimen before us (*Lign.* 124), which was formerly in the collection of Mr. Parkinson. The stem of this species is remarkable, from being constructed of ossicula alternately large and orbicular, and small and cylindrical, thus forming a column of great flexibility. The pelvis resembles in shape a depressed vase; the upper part of its cavity appears to have been closed by an integument protected by numerous plates, the mouth of the animal being situated near the centre.

It will elucidate this subject if we examine this specimen of a *Marsupite*, in which the bases of two of the arms are preserved (*Lign.* 147). A vertebral column attached to the central plate, at the base of this crinoidean, would convert it into an Encrinite; and in the large expanded plates of the receptacle, and the strong and simple ossicula of the arms, we have the elements of the more complicated and highly ornamented fabric of the Lily Encrinite. In another specimen of Marsupite (now in the British Museum) the plates which covered the opening of the receptacle are preserved.* The Marsupite may therefore be considered



LIGN. 147.—MARSUPITE FROM THE CHALK, NEAR ARUNDEL.

(*Collected and drawn by G. A. Coombe, Esq.*)

Fig. 1. A plate with the base of one of the arms attached. 2. Lateral view of one of the arms. 3. The *Ossicula*, by which the arms are attached to the body. 4. The Marsupite, with the first five ossicula of two of the arms attached to the brim of the ossicula.

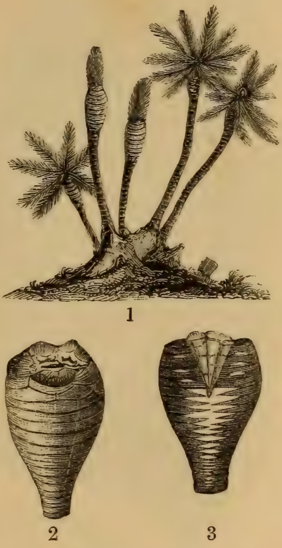
as a free Encrinus—a link that unites the Crinoideans with the Star-fishes; the form of the perfect skeleton was shown in a previous lecture, when treating of the Radiaria of the Chalk (p. 526).

42. PEAR ENCRINITE OF BRADFORD.†—A smooth species of Encrinite, which, from the body having a pyriform shape, has received the name of Pear Encrinite, occurs in con-

* See Fossils of the South Downs, Pl. XVI. fig. 6.
† Medals of Creation, p. 318.

siderable numbers in the oolite near Bradford in Wiltshire, under the interesting circumstances already mentioned (p. 505).

The receptacle of this Encrinite is very smooth, and crossed transversely by fine lines where the plates of which it is composed unite. The stem is short, smooth, and strong; the arms are simple, and bear considerable resemblance to those of the Marsupite. In this drawing (*Lign.* 148, *fig.* 1), reduced from Mr. Miller's beautiful work on the Crinoidea, a group of these animals is represented as if alive in the water. A few perfect specimens have been obtained; but the body is usually found deprived of the arms, and broken off at the top of the column (*fig.* 2): the vertical polished section (*fig.* 3), shows the form and arrangement of the plates composing the receptacle.



LIGN. 148.—PEAR ENCRINITE OF BRADFORD.

(*Apiocrinites rotundus.*)*

Fig. 1. A group of *Apiocrinites*, represented as alive in the water; some with the tentacula expanded, others closed.
2. Body of the Pear Encrinite.
3. A vertical section of the same.

A small species of this genus is found in the white chalk.†

43. PENTACRINITES, ACTINOCRINITES, &c.‡—In the

* From Mr. Miller's History of the Crinoidea.

† *Apiocrinites ellipticus;* Medals of Creation, p. 321, *Lign.* 71.

‡ "Medals of Creation," p. 321, *Lign.* 71.

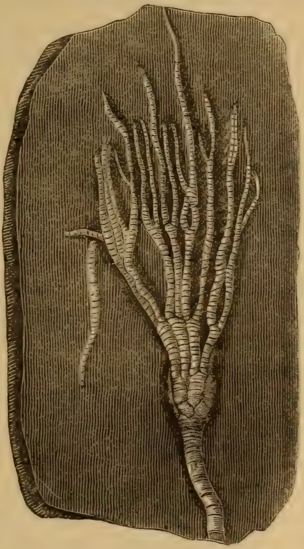
Pentacrinites the ossicula composing the columns are pentagonal, but in some species they have only four angles (*Lign.* 145, *fig.* 10); and in some the angles are acute, in

LIGN. 149.—CRINOIDEA FROM THE MOUNTAIN LIMESTONE, AND SILURIAN FORMATIONS.

Fig. 1. Cyathocrinites pyriformis, from the Wenlock limestone. (*Sir R. I. Murchison's Silurian System*, Pl. 17, fig. 6.)

2. Restored figure of Actinocrinites from the Mountain limestone. (*Miller's Crinoidea*, p. 96.) *a*, the root-like processes of attachment; *b*, the side-arms; *c*, the pelvis; *d*, the arms or tentacula.

others rounded. The stems are furnished with numerous side-arms (see the recent specimen, *Lign.* 144), and the tentacula subdivide into innumerable branches, which terminate in delicate articulated rays. Allusion has already been made (p. 526) to the abundance and extreme beauty of the Plumose Pentacrinites of the Lias shale at Lyme Regis, and other localities in Devonshire and Somersetshire.



LIGN. 150.—CUP-LIKE ENCRINITE.
(*Cyathocrinites planus.*)
From the Mountain-limestone, Clevedon, Somersetshire.

Many other genera of this numerous family have been discovered, and are figured and described by Miller and other naturalists.* In some instances the receptacle is closed, the tentacula being retracted or bent inwards, as if the animal had been in the act of conveying prey to its mouth, at the very moment of its becoming enveloped in its rocky sepulchre (*Lign.* 149, *fig.* 1). In other examples, the skeleton lies in relief, with the arms spread out as if the creature, while floating at its ease in the water, had been suddenly surrounded and entombed in the stone (*Lign.* 150). The elegant plumose encrinite termed *Actinocrinites*,† occurs in a beautiful state of preservation in the Mountain limestone; the form of the original is represented in this drawing (*Lign.* 149, *fig.* 2). The receptacle of the Actinocrinite is constructed of numerous plates, which in many species are richly ornamented; and some have the

* For a more particular account of the natural history of this tribe of animals, consult the second volume of Parkinson's Organic Remains; and Miller's Natural History of the Crinoidea, or Lily-shaped Animals, 1 vol. 4to. with numerous plates, 1827.

† *Actinocrites,* signifying the Radiated Lily-shaped animal.

surface granulated in a radiating manner, like those of certain varieties of the Marsupite. In another genus, the *Cyathocrinites* (*Lign.* 150), the receptacle is very simple, and composed of but few plates: the ossicula of the columns in the Actinocrinites and Cyathocrinites are round and smooth: a beautiful specimen of the cup-shaped Encrinite is represented, of half the natural size, in *Lign.* 150.

44. PENTREMITES AND CYSTIDEA.—The species and even genera of the fossil Crinoidea are so numerous, that their bare enumeration would require more space than we can allot to the subject, and I will only notice two of the most remarkable types.

Pentremites. These Lily-shaped animals seem to hold an intermediate space between the Echinites and the Encrinites. Their receptacle consists of five petaloid divisions united by corresponding series of plates, which meet in a point at the summit. Each petal is divided by a groove, and is perforated near the apex. They have a very short pedicle. These Crinoideans are so abundant in some of the cherty beds of the mountain limestones of Kentucky,* that the rocks have acquired the name of Pentremital limestone. Seven species occur in the mountain limestone of Yorkshire.

Cystidea. In the oldest of the fossiliferous strata there occur certain crinoideans, of a type which is supposed to be restricted to the ancient palæozoic periods. These fossils are distinguished by Baron Von Buch by the names of Cystidea. The receptacle is of an oval form, composed of numerous polygonal plates articulated together, and having the necessary apertures on the side of the cup required by the economy of the animal; it has a short pedicle. The Cystidea are supposed to be destitute of true arms, but some observers doubt the correctness of this conclusion; they comprise several genera, and are the first

* Journal of the Acad. Nat. Sciences of Philadelphia, for 1820.

forms in which the Crinoidea appear in the natural records of our planet.

And here I must conclude this very general notice of this interesting family of Crinoideans, which is of excessive rarity in the present seas, but swarmed in the ocean of the Silurian epoch, in various modifications of form and structure, all of which are now extinct.

45. CONCLUDING REMARKS.—From this review of the Polyparia and Crinoidea, we learn that an atom of living jelly floating in the ocean, and at length becoming affixed to a rock, may be the first link in a chain of events, which, after the lapse of ages, may produce important modifications in the physical geography of our globe. We have seen that the living polypes in their rocky habitations enjoy all the blessings of existence, and at the same time are the unconscious instruments of stupendous operations, which in after ages may affect the destinies of mighty nations; and that the materials elaborated by their agency, and subsequently consolidated by chemical changes, may become the foundations of Islands and Continents, and constitute new and favourable sites for the abode of future generations of the human race.

And when we bring the knowledge thus acquired to bear on the natural records of our planet, and examine the rocks and mountains around us, we find that in periods so remote as to exceed our powers of calculation, similar effects were produced by beings of the same type of organization as those whose labours have been the subject of our contemplation. We are thus enabled to read the history of the past, and to trace the succession of events, each of such duration as to defy all attempts to determine with any approach to probability the period required for its development.

In fine, these investigations have shown us the marvellous structure of creatures invisible to the naked eye, their modes of life and action, and the important changes effected in the relative proportion of land and water, by such apparently inadequate agents. They have instructed us, that above, beneath, and around us, there are beings so minute as to elude our unassisted vision, yet possessing sensation and voluntary motion, and each furnished with its systems of nerves, and muscles, and vessels, and preying upon creatures still more minute, and of which millions might be contained in a drop of water; nay, even that these last are supported by living atoms still less, and so on—and on—till the mind is lost in astonishment, and can pursue the subject no farther!

Thus are we taught,—

"That those living things
To whom the fragile blade of grass,
That springeth in the morn
And perisheth ere noon,
Is an unbounded world;—
That those viewless beings,
Whose mansion is the smallest particle
Of the impassive atmosphere,
Enjoy and live like man!
And the minutest throb,
Which through their frame diffuses
The slightest, faintest motion,
Is fixed, and indispensable,
As the majestic laws
That rule yon rolling orbs!"

SHELLEY.

We have contemplated the results produced by these countless myriads of animated forms,—the excess of calcareous matter brought into the waters of the ocean consolidated by their influence, and giving birth to new regions; and we have obtained evidence that in the earlier ages of our globe, like effects were produced by similar living instruments. The beds of fossil coral are now the sites of towns and cities, whose inhabitants construct their abodes of the limestones, and ornament their temples and palaces with the marbles, formed of the petrified skeletons of the zoophytes, which lived and died in oceans that have long since passed away!

Hence we perceive that He who formed the Universe creates nothing in vain; that His works all harmonize to blessings unbounded by the mightiest or the most minute of His creatures; and that the more our knowledge is increased, and our powers of observation are enlarged, the more exalted will be our conception of His wondrous works!

LECTURE VII.

THE CARBONIFEROUS SYSTEM.

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1. Introductory. 2. The Carboniferous System. 3. The Coal-measures. 4. Coal-field of Derbyshire. 5. Coalbrook Dale. 6. Nature of Coal deposits. 7. Mode of Deposition of the Coal-measures. 8. The Great Dismal Swamp of Virginia. 9. Erect Trees in the Carboniferous Deposits. 10. Upright Trees at Wolverhampton and St. Etienne. 11. Coal-measures of Nova Scotia. 12. Coal-shales and Vegetable Remains. 13. Millstone Grit. 14. Carboniferous Limestone. 15. Derbyshire Lead-mines. 16. Carboniferous system of Devonshire. 17. Trap rocks and Dikes of the Carboniferous system. 18. Faults in the Coal-measures. 19. Geographical distribution of the Carboniferous Strata. 20. Carboniferous System of North America. 21. Organic remains of the Carboniferous System. 22. Organization of Vegetables. 23. Climate and Seasons indicated by Fossil Wood. 24. Microscopical examination of Fossil Trees. 25. Nature of Coal. 26. Liebig on the formation of Coal. 27. Bitumen, Petroleum, Naphtha. 28. The Diamond. 29. Anthracite, Plumbago, &c. 30. Petrifaction of Vegetables. 31. Artificial Vegetable Petrifactions. 32. Silicification of Vegetables. 33. Fossil plants of the Coal. 34. Equisetaceous Plants. 35. Fossil Ferns. 36. Sigillaria. 37. Stigmaria. 38. Lepidodendron. 39. Coniferous Trees and Plants. 40. Flora of the Coal. 41. Atmospheric conditions during the Carboniferous epoch. 42. Formation of Coal-measures. 43. Coal-measures from submerged Lands. 44. Echinodermata of the Carboniferous System. 45. Shells of the Carboniferous System. 46. Crustaceans and Insects. 47. Fishes of the Carboniferous System. 48. Reptiles of the Carboniferous Epoch. 49. Climate of the Palæozoic Ages. 50. Retrospect and Botanical Epochs.

1. INTRODUCTORY. — From the contemplation of the changes produced on the earth's surface by the agency of minute beings whose nature and economy are known only to the instructed observer, we resume the geological argument from which we have for a while digressed, and enter upon the examination of the series of strata deposited during the period immediately antecedent to the Permian formation described in the fifth Lecture.

The *Carboniferous system*, so named from its comprising the principal deposits of mineral fuel, consists of sandstones, bituminous shales, bluish grey limestones, clays with iron ore, and quartzose grits; between which are intercalated seams and thick beds of the carbonized vegetable matter, termed Coal. Independently of the interest attached to these deposits from the immense accumulation of fossil plants of which many of them are wholly composed, this system involves the consideration of some very remarkable geological phenomena; for the manner in which such extensive layers of carbonized vegetable substances, unmixed with extraneous matter, were produced, is a problem difficult of solution, under certain conditions in which it is presented to our examination. Like the intercalation of the masses of rock-salt in the red marls of the Trias (*ante*, p. 539), the deposition of coal appears, as we shall presently show, to have taken place under various circumstances; the coal being in some cases associated with fresh-water, and in others with marine organic remains.

But though from the vast importance of mineral fuel in an economical point of view to nations in an advanced state of civilization, and the botanical interest with which such extensive natural herbaria of the palæozoic ages are invested, the coal is generally regarded as constituting the essential feature of this epoch, yet it would be more philosophical to consider these intercalations of carbonized vegetables, as extraneous and accidental. We have already seen, that the formation of coal was not confined to the carboniferous system; but that beds of this substance have been and will be produced, wherever trees and plants are accumulated in sufficient quantity, and under the requisite conditions.

The peculiar types of vegetable organization comprised in the flora of this system, afford the only distinguishing characters of the beds of coal interpolated in the strata, that were deposited during the ages intervening between the close of the Devonian epoch and the commencement of the Permian.*

The strata comprised in the carboniferous system form three natural groups, as shown in the following table ; and I propose to consider, in the first place, the general features of the deposits, and their geographical distribution ; secondly, the nature and formation of coal, and the characters of the fossil plants of which it is composed ; and, lastly, notice the animal remains, and take a retrospective view of the successive floras which have prevailed on the surface of the earth, during the epochs embraced by our geological investigations.

2. THE CARBONIFEROUS SYSTEM.—The following tabular arrangement exhibits the lithological characters and relations of these deposits :—

I. THE COAL MEASURES. Sandstone, shale, and grit, with numerous beds and layers of Coal; ironstone in nodules, and irregularly stratified. Intercalations of bands of limestone, with fresh-water shells and crustaceans. Total thickness, upwards of 1000 yards in some districts.

II. MILLSTONE GRIT. Coarse quartzose sandstone passing into a conglomerate used for millstones—hence the geological term; with shales and sandstones; containing interspersions of fossil plants and vegetable matter, and sometimes layers of coal. Total thickness, about 600 feet.

III. CARBONIFEROUS OR MOUNTAIN LIMESTONE. A series nearly 1000 feet in thickness of limestones and flagstones, containing corals, crinoideans, and marine shells in profusion. Beds of marble wholly made up of petrified zoophytes. Numerous cephalopoda and brachiopoda. This group is generally devoid of coal in England; but the mountain limestone of some parts of Russia contains extensive coal-mines.

The Mountain-limestone group rests upon the Devonian

* See remarks on the Coal of the Oolite, *ante*, p. 514 ; of the Wealden, p. 392; of the Tertiary, p. 278 ; and in peat, p. 60.

or Old Red sandstone, which was formerly included in the Carboniferous system, but is now regarded as a distinct formation, on account of a peculiar type of organic remains prevailing throughout.

3. The Coal measures. — The bituminous substance termed coal is simply vegetable matter altered by chemical changes, which will hereafter be considered. It occurs in beds that vary from a few inches to a fathom in thickness, and are interposed between strata of shale, clay, micaceous sandstone, limestone, and ironstone; alternations of this kind occupying circumscribed areas, are termed *coal-basins.* Mr. Bakewell observes that the strata thus disposed may be explained by a series of mussel-shells, placed one within the other, and having layers of clay interposed. If one side of the shell be raised to indicate the general rise of the strata in that direction, and the whole series be dislocated by partial cracks or fissures, the general arrangement of the beds and the displacements which they have undergone, will be represented; each shell being the type of a bed of coal, and the partitions of clay, of the earthy strata which separate the carboniferous layers.

It is the association of iron ore with the limestone that serves as a flux, and the fuel required for the reduction of the ore into a metallic state, that has given rise to the numerous iron-foundries which occupy the sites of our principal fields. The usual characters of a *Coal-field,* as a series of strata of this kind is termed, are shown in the section of that of South Gloucestershire, (*Lign.* 118, *ante,* p. 522.) Here we perceive that the Devonian, or Old Red-sandstone, has been elevated into a position almost vertical, and that the *Mountain limestone,* which lies immediately upon it, partakes of the same inclination. This is succeeded by conformable beds of *Millstone-grit,* which are followed by alternations of coal and grit; the *Trias, Lias,* and *Inferior Oolite,* (3, 4, 5,) are seen above in an unconformable position. The *Mountain limestone* and *Millstone grit* (1, 2) also appear on the opposite flank of the elevated ridge of the Mendips. It will be instructive to enumerate the deposits exhibited in this section, in chronological order; that is, in their original position before they had suffered displacement. Commencing with the lowermost or most ancient, the Devonian strata of the Mendip Hills, we have—1. Mountain limestone.—2. Millstone grit; upon this are alternations of coal and shale, with Pennant-grit.—3. New Red-sandstone.—4. Lias.—5. Inferior Oolite. —6. Great Oolite.—7. Oxford Clay, south of Malmsbury.

The term *basin*, applied to these accumulations of carboniferous strata, must be taken in a general sense; for though some of these groups of deposits may have been formed in circumscribed depressions, it is evident that, in general, the beds have extended over large areas, and that their present isolated and confined limits are attributable to subsequent elevations and depressions of the rocks on which they repose, and by which the faults and dislocations of the coal and associated strata have been produced.

4. COAL-FIELD OF DERBYSHIRE.—The Derbyshire Coal-field will serve as a type of the English series.

The strata of carboniferous limestone which form the grand mountain-chains of Derbyshire, decline towards the eastern side of the county, and sink beneath the coal-measures. Immediately upon the limestone is placed a bed of calcareous slate or shale, varying in thickness from three to six hundred feet. The compact strata are separated by coarse layers, which readily disintegrate, and these form the exposed face of Mam Tor, or the "*shivering mountain*," near Castleton. They are succeeded by a mass of grit, or conglomerate, with vegetable remains, which is worked for mill-stones. Above the millstone-grit are the regular coal strata, comprising sandstones of various qualities, and often in exceedingly thin laminæ; indurated clays; iron-stones, the nodules of which contain organic remains; and softer argillaceous beds, which being of a slaty structure, are called *shales*. Two of the layers of clay abound in fresh-water mussel-shells, of extinct species, and are termed *mussel-bind;* these bivalves very much resemble some of the small species of Unio of the Wealden (p. 404). The total thickness is 1310 yards, which includes thirty different beds of coal, varying from six inches to eleven feet, and making the amount of coal about twenty-six yards. In the shales below the coal, there is a transition from marine calcareous strata with animal remains, to fresh-water deposits, with terrestrial vegetables: this may have originated from occasional intrusions of freshes from a river.

The series above enumerated is often repeated; shales, clays, and sandstones occurring under different beds of coal, with a perfect similarity in the succession and thickness of each. Interruptions to the continuity of the beds, from cracks and fissures which have taken place since the original deposition of the strata, are everywhere apparent (see *Lign.* 152). Dikes or intrusions of extraneous mineral matter are of frequent occurrence, separating the strata by vertical walls, which are from a few inches to many yards in thickness. These intrusive masses sometimes consist of indurated clay, but more commonly of the ancient volcanic rock termed *basalt* or *trap*.

5. Coalbrook Dale.—In Shropshire the carboniferous strata occupy several detached areas.* Around Shrewsbury the coal-beds are associated with limestone of fresh-water or estuary origin, peculiar to the coal-fields of the central counties of England, and containing fresh-water crustaceans (*Cyprides*), shells, (*Cyclas, Planorbis, Unio*), and fishes. But the most important and productive carboniferous tract in Shropshire is *Coalbrook Dale*, which is

* Consult Sir R. I. Murchison's admirable description of the Carboniferous System; "Silurian System," chap. vi.

situated on the east side of the range of rocks forming the Wrekin and Wenlock Edge, the coal strata being superposed on mountain limestone; it contains beds and nodules of iron-stone, enclosing organic remains. This coal-field is remarkable for the dislocated and shattered condition of the strata, and the intrusion of volcanic rocks; the latter do not appear as dikes or veins, in the fissures of the beds, but rise up in mounds or protuberances. The walls of the fissures are in some instances several yards apart, the intervals being filled with debris. Strata containing marine shells, alternate with others abounding in fresh-water shells and land plants, as in Derbyshire. These alternations prove that these coal-measures were deposited in an estuary, subject to occasional freshes from a considerable river; the frequent alternations of coarse sandstones and conglomerates, with beds of clay and shale containing the remains of the plants brought down by the river, support this opinion.* The strata forming this carboniferous series, consist of quartzose sandstone, indurated clay, slate-clay, and coal. A pit sunk in Madely colliery, to a depth of 730 feet, passed through eighty-six beds of alternating quartzose sandstone, clay-porphyry, coal, and indurated clay containing nodules of argillaceous ironstone. The sandstones of Coalbrook Dale are fine-grained and micaceous, and some beds are penetrated by *petroleum*, which at Coalport escapes from the surface in a tar-spring; bitumen also occurs in some of the shales. Plants, shells, and crustaceans, are abundant in the shale and iron-stone nodules; and the remains of insects are sometimes met with.†

6. NATURE OF COAL DEPOSITS.—This brief notice of two of the British coal-fields will serve to convey a

* See a highly interesting memoir on this coal-field, by Mr. Prestwich; and Sir R. I. Murchison's "Silurian System," chap. vii.

† Medals of Creation, vol. ii. p. 575.

general idea of the strata of which a coal-basin consists. But it is necessary to enter more particularly on the nature and arrangement of the beds of coal, and their associated deposits; for though many accumulations of carboniferous rocks have manifestly been formed by different and local agencies, the grand series of ancient coal-measures, setting aside unimportant discrepancies, present a remarkable uniformity of character, not only throughout Great Britain and Europe, but also in most other parts of the world.*

We have seen that the strata constituting a coal-field are alternating layers of coal, clay, shale, and sand, of variable thickness, based either on grit, or limestone abounding in marine shells and corals. Now, a very remarkable fact is the uniform presence of a thick bed of earthy clay beneath every layer of coal, and a stratum of slaty clay or shale above it.

One of the series of which a coal-field consists presents, therefore, the following characters:—

(1.) Lowermost;—a stratum of clay, called from its position, the *under clay;* a tough argillaceous substance, which upon drying becomes a grey friable earth. Occasionally this clay is of a black colour from the presence of carbonaceous matter. This bed almost invariably contains an abundance of the fossil vegetables termed *Stigmariæ,*† which are generally of considerable length, and have their rootlets or fibres attached, and extending in every direction through the clay. These stems commonly lie parallel with the planes of the stratum, and nearer to the top than to the bottom.

* The various Memoirs on the British coal-fields in the Geological Transactions, by some of our most eminent observers, and in the works of Messrs. Bakewell, Conybeare, Phillips, Lyell, De la Beche, Buckland, Murchison, and others, will afford those who wish to pursue the inquiry, information of the most important and interesting nature.

† See Medals of Creation, p. 139.

(2.) *Coal.* A carbonized mass, in which the external forms of the plants and trees composing it are obliterated, but the internal structure remains. Large trunks, stems, and leaves, are rarely distinguishable in it.

(3.) *The Roof,* or upper bed. This generally consists of slaty clay, abounding in leaves, trunks, branches, fruit, &c.; and includes layers and nodules of iron-stone, inclosing leaves, insects, crustaceans, &c. In some localities beds of fresh-water shells, and in others of marine shells, are intercalated, and interstratified with the shale, finely laminated clay, micaceous sand, grit and pebbles of limestone, sandstone, and other rocks, often occur. The principal illustrative specimens of the leaves, fruits, &c. of the carboniferous flora, are found in this bed, which appears to be an accumulation of water-worn detritus of other rocks, promiscuously intermingled with the dense foliage and stems of a prostrate forest, the whole drifted from a distance by a strong current, or flood.

7. Mode of deposition of the coal.—Thus we have, in the first place, spread uniformly over the bottom, and constituting the foundation on which the coal reposes, a stratum of fine pulverulent clay, several feet thick, which, possibly, may have once constituted the soil of a vast plain or savannah. The only fossil remains found in it, except in a few localities, are the roots of the large trees of which the coal is in a great measure composed; for such the *Stigmariæ* now prove to be, and not aquatic plants, as was formerly supposed.*

* Medals of Creation, vol. i. p. 143. The invariable occurrence of the fossil roots, termed Stigmariæ, in the under-clay, and their rarity in the coal and shale, was noticed by Mr. Martin (*Petrif. Derbiensia*), Dr. Macculloch, and other observers: but the importance of this fact was not duly appreciated till Mr. Logan drew attention to it. In the Welsh coal-field, in a depth of twelve thousand feet, there are sixty beds of coal, each lying on a stratum of clay abounding in stig-

Upon this is deposited the coal; a bituminous mass of coniferous wood, gigantic ferns, club-mosses, &c. as we shall presently demonstrate; occasionally stems of trees are found passing vertically through this bed.

In the third place, we have a deposit of drifted materials promiscuously intermingled with the foliage and stems of numerous kinds of terrestrial plants; the whole appearing to have been subjected to the mechanical action of floods of water.

These facts seem to indicate that a bed of coal of this kind, is nothing more than a submerged forest. The *under-clay* may have been the natural soil in which the Stigmariæ, the roots of the trees forming the coal above, originally grew; the *coal*, the carbonized stems and foliage of the trees to which the roots belonged; and the *upper stratum* or roof, may have resulted from detritus transported from a distance by a debacle or flood, which overwhelmed and buried the foliage and stems of the prostrate forest.

These phenomena may be explained by supposing that a plain, densely clothed with vegetation, was inundated by an irruption of the sea; or overwhelmed by a flood of water from an inland lake, occasioned by the sudden removal of some barrier; or by the subsidence of the tract of country on which the forest grew. But when we find an uninterrupted series, in which triple deposits of this kind are repeated thirty or forty times, and through a thickness of several thousand feet, this solution of the problem, though very plausible, cannot, I apprehend, be deemed conclusive. Not only subsidence after subsidence must have taken place, but the first submergence have been followed by an elevation of the land; and then another soil capable of affording support to a second forest must have been produced, and another generation of vegetables, of the same species as the former,

mariæ. In the Appalachian coal-field of the United States, the same phenomenon appears.

have sprung up, and arrived at maturity: and again another subsidence, followed by an accumulation of drift. And these periodical oscillations in the relative level of the land and water, and successive reproductions of vegetable soil and of forests, must have gone on uninterruptedly through a long period of time: not in one district or country only, but in various parts of the world, during the same geological epoch.

8. THE GREAT DISMAL SWAMP OF VIRGINIA.—The formation of the coal-measures from terrestrial trees and plants, not drifted, but growing on the areas now occupied by the coal—a theory so generally adopted, that on a late discussion on the subject before the Geological Society of London, but one individual expressed dissent—is strongly advocated by Mr. Lyell: and the following observations of this profound geologist, on the "*Great Dismal Swamp*" of Virginia, in North Carolina, afford an interesting illustration of this hypothesis.

"The 'Great Dismal,' is a morass forty miles long, and twenty-five miles in its greatest width, and has the appearance of a broad inundated river plain, covered with all kinds of aquatic trees and shrubs, the soil being as black as in a peat-bog. It is one enormous quagmire, soft and muddy, except where the surface is rendered partially firm by a covering of vegetables and their matted roots; and is actually higher than nearly all the firm and dry land which encompasses it; and to make the anomaly complete, in spite of its semi-fluid character, it is higher in the interior than towards the margin. The soil of the swamp is formed of vegetable matter, usually without any admixture of earthy particles. We have here, in fact, a deposit of peat from ten to fifteen feet in thickness, in a latitude where, owing to the heat of the sun and length of the summer, no peat mosses like those of Europe would be looked for under ordinary circumstances. The juniper trees, or white cedars (*Cupressus thuyoides*) stand firmly in the softest part of the quagmire, supported by their long tap roots, and afford, with many other evergreens, a dark shade, under which a multitude of ferns, reeds, and shrubs, from nine to eighteen feet high, and a thick carpet of mosses, spring up, and are protected from the rays of the sun. Where these are most powerful, the large cedar (*Cupressus disticha*), and many other deciduous trees, are in full leaf. The black soil formed beneath this shade, to which the mosses and leaves make annual additions, is a soft black mud, without any traces of organization. Numerous trunks of large and tall trees lie buried in the black mire of the morass. In the midst of the swamp there is a lake of an oval form, seven miles long, five wide, and the depth, where greatest, fifteen feet; its bottom consists of mud like the swamp, but which in some places is covered by a pure white sand, a foot deep. This sheet of water is usually even with the banks, on which a tall and thick forest grows.

"The phenomena above described help us greatly," observes Mr. Lyell, "to conceive the manner in which the coal of the ancient carboniferous rocks may have been formed. The heat, perhaps, may not have been excessive when the coal-measure originated, but the entire absence of frost, with a warm and damp atmosphere, may have enabled tropical forms to flourish in latitudes far distant from the line. The frequent submergence of masses of vegetable matter like the morass, beneath seas or estuaries, as often as the land sank down during subterranean movements, may have given rise to depositions of strata of mud, sand, or limestone, immediately upon the vegetable matter. The conversion of successive surfaces into dry land, on which other swamps supporting trees were formed, might give origin to a continued series of coal measures, of great thickness."*

The above is a concise exposition of this theory by one of its ablest advocates, and is therefore deserving every consideration; but until it can be shown that pure beds of coal are being formed under such conditions, the hypothesis, however ingenious, appears to me to be without any support from facts. To render the "Great Dismal" a modern example of the mode in which the ancient coal-measures were formed, it is necessary to obtain evidence that beds of coal have been and are still being produced in this morass.

9. Upright Trees in the Coal Measures.—The occurrence of trees in an upright position, in some instances with their roots attached, and extending into the under-clay, is regarded as another unequivocal proof of the formation of coal from vegetables growing on the spot. Several instances of this kind have been observed in England. One of the most remarkable was brought to light a few years since in forming the Bolton and Manchester railway. Near Dixon-

* Travels in America, vol. i. chap. vii.

fold, five large stems (*Sigillariæ*) were found erect, with their roots extending into a layer of impure clay below. They stood on the same plane, and near to each other The trunks were surrounded and filled by a soft blue shale, the carbonized bark being all that remained of the original structure. The stems are gnarled and knotted, and have decorticated prominences, like those in barked trunks of our old dicotyledonous trees. All these trunks appear to have been broken off by violence, at a height of four or five feet above the roots, and no traces of the upper part of the stems or branches were detected.*

In constructing the railway tunnel at Clay-cross, a few miles south of Chesterfield, through the middle portion of the Derbyshire coal-measures, in 1838, a group of nearly forty trees (*Sigillariæ*) was discovered. These stood at right angles to the planes of stratification, and not more than three or four feet apart.†

On the coast of Northumberland, within the length of half a mile, twenty upright trees were observed by Mr. Trevelyan; and similar fossils were noticed many miles distant from this spot, in the same coal-field; as if they were a continuation of a submerged forest, the trees of which had maintained their erect position, like those of the Isle of Portland (*ante*, p. 387). Examples of isolated upright trunks, with more or less of the roots attached, are not uncommon. In the Derwent mines, at the depth of fifty-five fathoms, among numerous examples which were lying in horizontal layers, were several in an erect position. Two stems of Sigillariæ, situated in the space cleared out to get at the lead ore, stood upright, having their roots firmly impacted in a bed of bituminous shale; they were five feet high, and two in diameter.‡

* Medals of Creation, vol. i. p. 131. † Geol. Proc. vol. iii. p. 270.

‡ Observations on Fossil Vegetables, by Henry Witham, Esq. 1 vol. 4to; Edinburgh, 1831.

In the Newcastle coal-field, a stratum of sandstone occurs 150 yards below the surface, in which were observed many erect stems of trees, from two to eight feet in circumference, having their roots in a thin layer of coal.

10. Upright Trees at Wolverhampton and St. Etienne.— "In a colliery near Wolverhampton the bottom coal rises to view, and where the surface has been cleared of the alluvial covering, it presents the appearance of a moor on which a full-grown fir-wood had been cut down a few months before, and only left the stumps behind. Stump rises beside stump, to the number of seventy-three in all: the thickly clinging roots strike out on every side into what seems once to have been vegetable mould, but now exists as an indurated brownish-coloured shale. Many trunks, sorely flattened, lie recumbent on the coal; several are full thirty feet in length, while some of the larger stumps measure rather more than two feet in diameter. There lie, thick around, Stigmariæ, Lepidodendra, Calamites, and fragments of Ulodendræ; and yet with all the assistance which these lent, the seam of coal formed by this ancient forest does not exceed five inches in thickness. Not a few of the stumps in this area are evidently waterworn. The prostrate forest had been submerged, and mollusks lived and fishes swam over it. This upper forest is underlaid by a second, and even a third: we find three full-grown forests closely packed up in a depth of not more than twelve feet."*

A coal-pit at Treuille, near St. Etienne, in France,† described by M. Alexandre Brongniart, contains many stems of Calamites and other trees in an erect position, and this fact is generally considered as an indisputable proof that the coal was produced by the submergence of a forest that once grew on the spot: but as many of these stems are inclined at various angles, and their roots implanted in

* First Impressions of England and its People, by Hugh Miller p. 223.

† In the department of the Loire.

different beds, the perpendicularity of the upright trees is probably accidental. This mine is most favourable for observation, for it is in the open air, and exposes to view a natural section of the strata of clay, slate, and coal, with four layers of compact iron ore, in flattened nodules, which are accompanied, and even penetrated, by vegetable remains. The upper ten feet of the quarry consist of micaceous sandstone, which is in some instances stratified, and in others possesses a slaty structure. In this bed are numerous vertical stems traversing all the strata, and appearing like a forest of plants resembling the *Bamboo*, or large *Equiseta*, turned into stone, in the place on which it grew. The stems are of two kinds: the one long and slender, from one to four inches in diameter, and nine or ten feet high, being simply jointed and striated, solid cylinders of sandstone, with a thin coaly bark. The other, and less common species, are hollow cylindrical stems, spreading out from the base like a root, but without ramifications.*

11. UPRIGHT TREES IN THE COAL MEASURES OF NOVA SCOTIA.—Though it is unnecessary to multiply examples of the occurrence of trees in an upright position in the carboniferous deposits, this phenomenon is so strikingly displayed in the coal measures of Nova Scotia, and has been so graphically described by Mr. Lyell, that I cannot omit a short abstract of his observations on the erect stems in the cliffs of the Bay of Fundy:—

"In the coal measures on the southern shores of a branch of the Bay, there are ten successive stages of erect trunks of trees, placed at right angles to the planes of stratification, through a thickness of strata of 2,500 feet; the entire series of deposits is estimated to be five miles in thickness. The strata are inclined at an angle of between 25° and 30°. The coal measures rest upon red sandstone and marls, and are overlain by shales containing modiolæ. The trunks of the trees are mere hollow

* Notice sur des Végétaux Fossiles traversant les couches du Terrain Houiller, par M. Alex. Brongniart, à Paris, 1821.

cylinders filled with sand and clay, consisting of the bark in the state of pure coal; as in the fossil trees in the Isle of Wight (*ante*, p. 380). A trunk, fourteen inches in diameter, had a coating of bark a quarter of an inch thick. No appearance of roots was perceptible; and the bottoms of the trunks *touched a subjacent bed of coal.*" Beds of bituminous shale and clay with Stigmariæ, ten feet thick, are described as overlying one series of upright trees, and upon these was another bed of coal, one foot thick, that supported two trees, each eleven feet high, and sixty yards apart; *they appeared to have grown on the coal.**

Mr. Lyell observed seventeen upright stems, at ten distinct levels. The nature of the wood is not stated, except that the trunks resembled those found erect at Dixonfold, in England.† The surrounding strata abound in Sigillariæ, Stigmariæ, and the other usual vegetables of the European coal strata. At Pictou, a hundred miles to the eastward of the Minudie coal measures, the same group of deposits occurs, and yields a large supply of coal. In this locality there is a row of upright *Calamites,* in sandstone, all terminating downwards at the same level, where the sandstone joins a layer of coarse grey limestone with pebbles. The tops of the Calamites are broken off at different heights, where the grit becomes coarser. The bed of erect Calamites at St. Etienne (*ante*, p. 673) is regarded by Mr. Lyell as analogous: and he considers both localities as affording unequivocal proof of fossil trees occupying the ground on which they originally grew.‡

To account for the successive stages of these erect trees, on the supposition that the trunks are now standing in their original position, we must suppose periodical elevations and subsidences of the land to have taken place. "It by no means follows," observes Mr. Lyell, "that a sea four or five miles deep was filled up with sand and sediments. On the contrary, repeated subsidences, such as are required

* See Mr. Lyell's Section of the Cliffs of the South Joggins, near Minudie, Nova Scotia. Travels in America, vol. ii. p. 180, fig. 21.

† Geol. Trans. vol. iii. p. 139. ‡ Travels in America, p. 195.

to explain the successive submergence of so many forests which grew one above the other, may have enabled this enormous mass of strata to have accumulated in a sea of moderate depth."*

In *Lehigh Summit* mine, there is a bed of anthracite fifty feet thick, with no interpolated detritus except two thin layers of clay with stigmariæ. Mr. Lyell considers it difficult to explain such an accumulation of pure vegetable matter, upon the hypothesis of the trees having been drifted, but intelligible, if we suppose them to have grown on the spot: yet he infers that to produce such a layer of coal, the original mass of vegetables must have been between three and four hundred feet in thickness;†—but where are there any indications of the soil on which such forests grew?

12. COAL-SHALES AND VEGETABLE REMAINS.—I have already stated that it is the shales, or slaty coal of the roof, from which the most abundant and illustrative examples of the plants of the carboniferous epoch are obtained; in many layers, vegetable remains occur between every lamina, the entire mass being formed of carbonized leaves and stems, closely pressed together in clay. The carbonaceous matter is sometimes in an unconsolidated state, exhibiting the matted fibres, leaves, and stems. This condition, indicating an intermediate stage in the formation of coal, is not of unfrequent occurrence in the upper secondary and tertiary carbonaceous deposits, but is rare in the most ancient.‡

The roof of a coal-mine when newly exposed displays the most interesting spectacle imaginable; leaves, branches, and stems of the most elegant and delicate forms, being embossed on the dark shining surface. The coal-mines of Bohemia, the fossil plants of which are well known, from the beautiful work of Count Sternberg, are stated

* Travels in America, p. 190.
† Ibid. p. 85.
‡ Silurian System, p. 100.

by Dr. Buckland to be the most interesting of any he has visited—but I will describe them in his own eloquent language. "The most elaborate imitations of living foliage on the painted ceilings of Italian palaces, bear no comparison with the beauteous profusion of extinct vegetable forms, with which the galleries of these instructive coal-mines are overhung. The roof is covered as with a canopy of gorgeous tapestry, enriched with festoons of the most graceful foliage, flung in wild irregular profusion over every portion of its surface. The effect is heightened by the contrast of the coal-black colour of these vegetables with the light ground-work of the rock to which they are attached. The spectator feels transported, as if by enchantment, into the forests of another world; he beholds trees of form and character now unknown upon the surface of the earth, presented to his senses almost in the beauty and vigour of their primeval life; their scaly stems and bending branches, with their delicate apparatus of foliage, are all spread forth before him, little impaired by the lapse of indefinite ages, and bearing faithful records of extinct systems of vegetation, which began and terminated in times of which these relics are the infallible historians. Such are the grand natural herbaria wherein these most ancient remains of the vegetable kingdom are preserved in a state of integrity little short of their living perfection, under conditions of our planet which exist no more."*

13. Millstone Grit.—The principal coal measures are generally superposed on the group of deposits designated by this term; but in some districts, these strata are wanting, or appear as a cherty, and sandy rock. The most characteristic bed of this series is the quartzose conglomerate, termed millstone-grit, which consists of rolled fragments of quartz-rock and granite, of various sizes, from a pear to that of a large pebble, cemented together in

* Bridgewater Essay, p. 458.

some instances by an argillaceous, in others by a crystalline siliceous paste. Sandstones composed of the fine detritus of similar materials are associated with the grit. Waterworn fragments of shale, coal, red-sandstone, stems of plants, &c. all bearing marks of transport by currents and streams, are also often found imbedded therein. Beds of coal are occasionally interpolated in this series, and in some localities the lowermost strata consist of shales with coal-plants, and contain nodules of ironstone similar to those of the upper coal strata, and veins of lead and copper. Satin-spar, and naphtha, petroleum, and other bituminous substances, occasionally occur in the shales of this series.

In Yorkshire the millstone grit becomes a very complex deposit, containing several subordinate beds of coal ; and is separated from the great inferior calcareous group (known in the north of England as the *Scar* limestone), not merely by shales and shaly limestones as in Derbyshire, but by deposits, not less than 1000 feet thick, in which five series of limestone strata, remarkable for their continuity and unvarying thickness, alternate with great masses of sandstone and shale, containing innumerable impressions of coal-plants, and a few seams of coal.*

14. Carboniferous or Mountain Limestone.†—The third and lowermost series of the carboniferous system, is an extensive assemblage of calcareous strata, composed for the most part of subcrystalline grey limestone, disposed in beds of considerable thickness ; the strata through a depth of many hundred feet being separated only by very thin clay partings. Shales, grits, and amygdaloidal rocks, are intercalated in certain localities ; and the principal beds of

* Professor Sedgwick, " Address to the Geol. Soc." 1831.

† This calcareous rock is also called *metalliferous limestone,* from its abounding in lead and other metallic ores : and *encrinital limestone,* from the prevalence of crinoideal remains in some of the beds (*ante,* p. 649).

coal used for economical purposes, are in some countries situated in this division of the system. Layers and nodules of chert occasionally traverse the limestones, like the flints in chalk.

The term *Mountain limestone*, applied to these calcareous rocks, has originated from their often forming elevated mountain chains, as in Derbyshire, Yorkshire, Somersetshire, &c. giving rise to scenery which equals, if not surpasses, in picturesque beauty that of any other part of England. I need but mention the vale of the Avon at Clifton, Matlock-dale, Dovedale, the escarpments that overhang the Wye near Chepstow, &c. The magnificent gorge of the Avon at Clifton is flanked by an uninterrupted succession of mural precipices, known by the name of St. Vincent's Rocks, and presents an unrivalled natural section of the carboniferous limestone. The calcareous beds rest conformably on strata of the Devonian system, which may be seen on both sides the river, near Cook's Folly, extending on the south under Leigh-down and Weston-down.*

This series of strata is also remarkable for the deep chasms and fissures by which the rocks are traversed; the principal caverns of this country being situated in them; those of Derbyshire, Yorkshire, Somersetshire, &c. are well known. Subterraneous rivers are likewise frequent throughout the districts formed by these deposits.

The mountain limestone is largely developed over the central and northern parts of England, and the south-west of Scotland: and is the predominant rock throughout a great part of Ireland. In Somersetshire, Gloucestershire, Shropshire, North and South Wales, and Derbyshire, it constitutes as it were an entire calcareous mass, which is interposed between the Devonian group; or, where that is wanting, between the more ancient Silurian rocks below,

* See Excursions to Clifton and Matlock-dale, and Crich Hill; Medals of Creation, vol. ii. pp. 929, 933.

and the sandstone and shales of the Coal above. In Cumberland and Westmoreland, &c. it appears as an elevated belt, which partly surrounds the Cumbrian slate mountains, and forms, on the west, a ridge nearly three thousand feet in height.

In Northumberland the mountain limestone with its associated millstone-grit, occupies large areas, and constitutes ranges of hills of considerable elevation ; the geographical features strongly contrasting with those of the adjacent country on the south, which consists of the coal-bearing strata, spread out in a plain of great extent.

In Derbyshire the grand physical features of the country are produced by the mountain limestone, which rises into crags or peaks, and hills, presenting bold precipitous escarpments, and produces the wildest and most picturesque scenery. Professor Phillips estimates the thickness of the lower division of limestones with shale partings (provincially termed *scar-limestones*), in Derbyshire, at 750 feet ; the alternations of shale, sandstone, limestone, and ironstone, which surmount the former, at 500 feet ; and the cappings of millstone-grit which form the summits of the hills, at 360 feet.

The carboniferous limestone, though some of the beds are destitute of fossils, is for the most part largely made up of corals, shells, crinoidea, &c. ; and which often form three-fourths of the mass. We reserve a more particular notice of these organic remains for a subsequent part of this Lecture. The Derbyshire encrinital marbles (*ante*, p. 650), and the coralline marbles of St. Vincent's rocks, near Clifton, are well-known examples of the finer compact varieties of these calcareous deposits.

The chert, where interpolated among the crinoideal remains, contains beautiful casts and impressions of the stems and ossicula, and also of the associated shells, in consequence of the siliceous matter which flowed into, and surrounded these bodies, having resisted the chemical action that subsequently destroyed the calcareous structure of the originals.*

15. Derbyshire lead-mines.—It is in the mountain limestone that the principal British lead-mines are situated, namely, those of Somersetshire, Derbyshire, York, Durham, and Northumberland. In Derbyshire the metal occurs in numerous veins which traverse the strata, and extend in some instances into the *toad-stone;* a volcanic rock we shall describe in the sequel. The perpendicular, or rake-veins as they are termed, are from two to forty feet wide; and there are chasms or hollows in the rock, several hundred feet in width, which also contain metallic ores and spars. Manganese, copper, zinc, and iron, are found in the limestone; but the predominating metalliferous ore is the sulphuret of lead, or galena, as it is called by mineralogists. This substance is of a bluish-grey colour, and often occurs in cubic and octahedral crystals; it is also disposed in thin layers, as well as in veins. It is accompanied by fluor and calcareous spar, sulphate and carbonate of barytes, iron pyrites, &c. The variety termed specular galena, or *slickensides*, is a thin coating of lead on the sides of the veins, and appears to have arisen from one wall of the fissure having slipped along the face of the other, so as to give it a polished or *slicken* surface.

The beautiful mineral known by the name of *Derbyshire spar*, is a fluate of lime, and occurs in crystals, and also in nodules. The celebrated spar, provincially called *Blue-John*, so much in request for vases, and other ornamental purposes, is found in the state of veins, and in large irregular masses from three inches to a foot in thickness, in the Odin mines, near Castleton.

The structure of the country around Matlock, and the

* See the pulley-stone, *Lign.* 145, *fig.* 1, which is a siliceous cast of an encrinital column.

principal metalliferous districts of Derbyshire, are so fully described in various works, that a brief notice of the manner in which the mineral and metallic productions occur, will suffice.

The chasms in the limestone exposed in some of the quarries, are often more or less incrusted with minerals and spars, and exemplify the mode in which the rich metallic veins of lead are distributed in the interior of the mountains.* A fissure which I observed in a quarry in Crich Hill, will serve as an illustration. A layer of the blue sulphuret of lead, or *galena*, was spread over the surface of the limestone that formed the walls of the fissure, and upon this was deposited a thick stratum of white sulphate of barytes: on the latter was a coating of fluor spar of a light blue colour, crystallized in cubes on the surface, and the cavity left in the rock was lined with cubic crystals of fluate of lime.†

16. CARBONIFEROUS SYSTEM OF DEVONSHIRE.—The rapid sketch I have given of the principal features of the three groups of strata composing the Carboniferous system, affords a general idea of the prevailing characters of this important formation. There is, however, an extensive series of rocks, which belong to this epoch, but occur under conditions that rendered their relations somewhat obscure, and occasioned them to be classed with the more ancient beds, until the investigations of Professor Sedgwick and Sir R. I. Murchison demonstrated their true position in the chronological arrangement of the British strata. This group consists of shales and slaty coal, provincially called *culm*, constituting a trough of carboniferous deposits superimposed on Devonian sandstone, but much dislocated and altered in character by intrusions of granite and other

* See "Excursion to Crich Hill:" Medals of Creation, vol. ii. p. 951.

† Ibid. p. 955.

rocks. By a careful examination of the plants and other organic remains, these culmiferous beds are found to be connected with the Trias above, and the Devonian below: the latter being characterized by its peculiar fossils, and passing into the Silurian system.

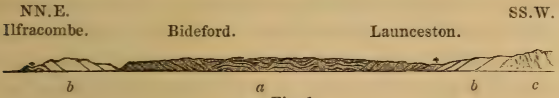


Fig. 1.

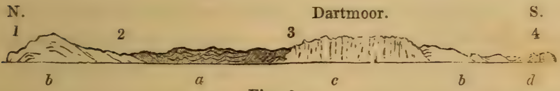


Fig. 2.

1. North Foreland. 2. Barnstaple. 3. Oakhampton. 4. Start Point.

Lign. 151.—Section of the Strata of Devonshire.

(*Professor Sedgwick and Sir R. I. Murchison.*)

Fig. 1. Section from NN.E. to SS.W. showing the carboniferous strata (*a*) in the centre, resting on each side on slates and sandstone of the Devonian system (*b*, *b*); a protrusion of granite (*c*) occurring on the SS W.

— 2 Section from north to south: the carboniferous beds (*a*) repose on Devonian strata on the north (*b*); while on the south the granite of Dartmoor has been protruded (*c*); the Devonian system (*b*) re-appearing in the southern part of the county, terminated by a band of micaceous schists (*d*).

a, Carboniferous system: the culmiferous rocks of Devonshire.
b, Devonian or Old Red system, consisting of slaty rocks, sandstone, and limestone.
c, Granite.
d. Micaceous schists; altered or metamorphosed strata.

The culmiferous deposits of Devonshire were probably once connected with the coal formation on the north side of the Bristol Channel: the vegetable fossils which they contain are identical with those of the coal basin of South Wales. These sections (*Lign.* 151), by the eminent geologists above named, will serve to illustrate the subject, and render details unnecessary. In the section (*fig.* 1) from NN.E. to SS.W. the culmiferous beds (*a*) are seen to form a trough, and repose on each side on the slates and calcareous sandstones (*b*, *b*) of the ***Devonian*** or Old Red system. The section (*fig.* 2), from north to south, shows the carboniferous strata (*a*), flanked on the north side only by the Devonian slaty rocks (*b*), the granite of Dartmoor (*c*) having been protruded on the southern edge; while the Devonian system re-appears in the southern part of the county, terminated by a band of micaceo-chloritic schists, which are parallel to the great disturbing axis of Cornwall and Devon, and are probably altered or metamorphosed sedimentary deposits.*

17. TRAP ROCKS AND DIKES OF THE CARBONIFEROUS SYSTEM.—The coal and its associated strata everywhere exhibit proofs of the violent subterraneous movements they have undergone since their original deposition: and but few coal-fields are free from extensive faults and dislocations, by which the beds have been broken up and thrown into different levels and positions. The entire group is also often traversed by veins and dikes of intruded volcanic rocks; generally consisting of the hard, dark green, fine-grained stone, called *trap*.

In Yorkshire there is a trap-dike of prodigious extent and thickness, named the *Whin-sill*, which traverses the coal-measures, triassic sandstone, and lias, and passes from High Teesdale to the confines of the eastern coast; a distance of upwards of sixty miles.

In Derbyshire, a trap-rock, which is in many parts amygdaloidal, and from being mottled with green and yellow has received from the miners the name of *toad-stone*, is interpolated between the beds of mountain limestone of that country, under circumstances of considerable interest.

These phenomena can nowhere be studied with more advantage than in the neighbourhood of Matlock, which

* Classification of the older stratified rocks of Devonshire and Cornwall, by the Rev. Professor Sedgwick and Sir R. I. Murchison. Annals of Philosophy, No. 89. April 1839.

is a region of carboniferous limestone, broken up and traversed by volcanic rocks.

The basalt or trap of Derbyshire was evidently erupted in a state of fusion, from some very deep-seated source of intense heat, and intruded between the limestone beds in three principal currents, which now appear as alternations of trap-rock with sedimentary strata: but which there is every reason to believe sprung from one common source, and are lateral protrusions from the great mass of igneous matter. The *toadstone* is a hard rock, consisting of small nodules of white and yellow calcareous spar and green earth, imbedded in a dark greenish paste of basalt. Sometimes the nodules are decomposed, and the stone is then vesicular or cellular, resembling porous lava. Three distinct beds of this ancient lava-current are interpolated in the mountain limestone of this district; the thickness of each varies from sixty to eighty feet. In some instances, dikes of toadstone traverse the metalliferous veins, and a manifest alteration is then observable in the nature of the latter.*

In some places the elevatory movements have torn the rocks asunder; in others the strata have partially resisted the expansive effect of the erupted lava, and are now in a dome-shaped or arched position, and more or less bent and folded.

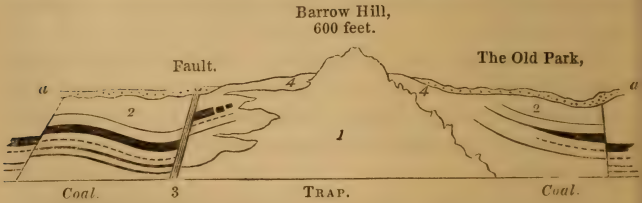
Crich Hill, near Matlock, affords a highly interesting illustration of this effect of igneous action. It is a dome-shaped hill of mountain limestone, 800 feet high, consisting of arched strata, enfolding a central mass of trap. This dome of limestone has been forced up through the once

* In the cavern at the base of the High Tor in Matlock Dale, a bed of toadstone is seen on the floor, beneath the limestone strata of which the cliff is composed, and may be traced across the river to the opposite escarpment of Masson's Hill, where it is exposed on the road-side. See Medals of Creation, vol. ii. p. 945.

superincumbent strata of millstone-grit, which now form a broken, and highly inclined wall around it. Such is Crich Hill—a stupendous monument of one of the past revolutions of the globe—with its arches of rifted rock teeming with mineral veins, and resting on a central mound of molten rock, now cooled down into an amorphous mass of compact basalt.*

A dike of the volcanic rock called green-stone, in some places eighteen yards wide, and which has been traced nearly seventy miles, traverses the Newcastle coal measures on Cockfield-fell. The coal, at the distance of fifty yards from the dike, is altered in its character, and near its contact with the erupted mass is reduced to half-burnt cinder, and sooty coaly matter. Wherever trap traverses coal-deposits, more or less change is always observable in the carbonaceous materials.

18. FAULTS IN THE COAL-MEASURES.—In illustration of the displacements called faults, in carboniferous strata,



LIGN. 152.—ERUPTED TRAP-ROCK, IN THE DUDLEY COAL-FIELD.

(*Sir R. I. Murchison's Sil. Syst.*)

1. Erupted Trap-rock.
2. Coal-measures.
3. Barrow Fault: upcast of 90 yards.
4. Coal, charred, and altered from contact with the Trap.

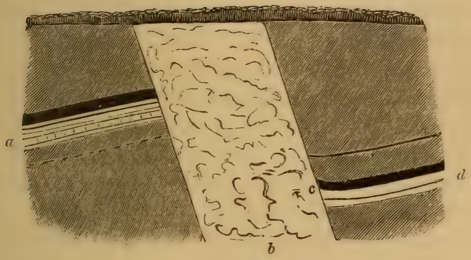
a, a, Alluvial soil.

I shall select a remarkable one that occurs in the Dudley Coal-field, near Barrow Hill (*Lign.* 152). The central mass

* See Medals of Creation, p. 951.

of erupted trap which has occasioned the dislocation, rises to the surface, and forms the summit of Barrow Hill; an elevation of about 600 feet. The displacements of the strata on each side of the volcanic rock have produced two lines of fault: and the coal in contact with the igneous rock, as is usual under such circumstances, is charred, and deprived of its bituminous quality.

In the principal fault, the coal-beds are rent asunder to an extent of 140 yards; and in the part represented in the sketch (*Lign.* 153), the erupted mass (*b*) has upcast the strata on the south-east ninety yards (*a*); the sides of the fissure being inclined from eighty to ninety degrees; thus the strata (*a*, *d*,) which were originally continuous,



Trap.

LIGN. 153.—SECTION OF A FAULT IN THE DUDLEY COAL-FIELD, NEAR BARROW HILL.

a, *d*, Carboniferous strata; the black line denotes the main bed of coal; *b*, Intruded Trap; *c*, the upward twist of the bed of coal *d*, where in contact with the Trap-dike.

and horizontal, have been separated, and the edges of the lower bed of coal twisted upwards, as is shown at *c*, by the intruded trap. These carboniferous strata are superimposed on red conglomerate. We shall have again occasion to notice the displacements in the Dudley Coal-field, when treating of the trappean ridges of that part of England.

The faults and dislocations of the strata are so numerous in many coal-fields, that they have been very aptly compared by Dr. Buckland to a fractured sheet of ice:—"If we suppose a thick sheet of ice to be broken into fragments of irregular area, and these fragments again united after receiving a slight degree of inclination to the plane of the original sheet, the reunited fragments of ice will represent the appearance of the broken masses or sheets of coal strata. The intervening portions of more recent ice, by which they are held together, will represent the clay and rubbish that fill the faults, and form the partition walls that insulate these adjacent portions of strata, which were originally formed, like the sheet of ice, in one continuous plane."*

There is a circumstance connected with the upheaving and disruption of the carboniferous strata, and which is also observable in other loosely aggregated deposits, that demands attention. However great the uprise or downcast of the rocks on one side of a fault, it is seldom that there are any external indications of the displacement visible; as for example in the fault of Barrow above sketched (*Lign.* 153).† The removal of the upraised masses has doubtless, in many instances, been occasioned by debacles or floods of water that have swept over the surface of the country; but in those cases in which the elevated strata were of great extent, and the displacement involved large areas, it is probable that the removal was effected by the action of the sea, when the rocks were first dislocated and

* Bridgewater Essay.

† Mr. Bakewell has treated this subject with great ability: see chap. ix. "On the general removal and disappearance of the coal strata, raised by faults above the surface of the ground."—*Introduction to Geology,* 5th edit. p. 200.

forced upwards, and before they emerged above the waters. In other instances, the disintegration may have taken place during their gradual elevation, in like manner as the removal of the chalk, and denudation of the underlying Wealden of the south-east of England, were produced.*

19. GEOGRAPHICAL DISTRIBUTION OF THE COAL-MEASURES. — Although the geological map (*Plate* I. p. 463) is on so small a scale, it will serve to convey a general idea of the geographical position of the areas occupied by the carboniferous strata of England. The principal coal basins are those of Somersetshire, Gloucestershire, North and South Wales, Dudley, Shropshire, Leicestershire, Lancashire, Nottingham, Derbyshire, Yorkshire, Cumberland, Durham, Newcastle; of the Forth and Clyde; and the central districts of Ireland. By far the greater part of the coal of Ireland is pure anthracite: there are several coal-basins exclusively of this mineral in five or six counties in the south of the Island.

On the Continent, coal, with limestones and red conglomerates, in some instances resembling, in others differing from the English strata, occur in France, near Boulogne, Mons, and St. Etienne; in the Low Countries, at Namur and Liege; in Germany, Silesia, Moravia, Poland, and in the Carpathian Mountains. The mountain limestone tract along the Meuse, in the Netherlands, resembles that of Derbyshire and Monmouthshire, and appears to be of the same age; and the scenery to which it gives rise will remind the English traveller of the banks of the Derwent or the Wye.

In many parts of France and Germany there are isolated patches of coal strata, entirely free from marine fossils, which repose on granite and other hypogene rocks: they

* See my Geology of the S. E. of England, chap. ix.; or, Excursions round the Isle of Wight, p. 74.

are, however, confined to small areas: as in the Department of the Loire, at Brassac, in Silesia, and many other places. All these deposits have been formed in lakes, existing in the islands of that sea in which the mountain limestone was deposited.*

Throughout the Russian Empire the productive coal beds are situated in the mountain limestone: but in Poland and Silesia, the coal measures are interstratified with shales and sandstones which overlie the mountain limestone, as in England and Belgium.

The Russian carboniferous strata are unquestionably fluvio-marine; for through a thickness of eight hundred feet, limestones, grits, and shales, abounding in marine shells, alternate with beds of coal. The vegetables of which the coal is formed, consist of broken and drifted plants, carried into the sea by inundations and freshes of rivers; the layers of clunch or finely levigated shale which support the coal-seams, may have originated from the earthy debris brought down by the floating masses of terrestrial plants.†

* Mr. Lyell's Elements of Geology.

† Sir R. I. Murchison. — The following remarks of an eminent French geologist, M. Constant Prevost, are especially worthy of attention in relation to this subject:—" On n'a pas assez réfléchi lorsque l'on a dit que les formations fluvio-marines n'étaient que des accidents locaux d'embouchure et de golfe; on pourrait presque avancer, sans paradoxe, que dans certaines mers bordées de vastes continents, les eaux douces affluences produisent plus dans la mer, que les eaux marines elles-mêmes. Le Mississipi et ses tributaires enlèvent au continent qu'ils traversent, plus de matières sédimentaires et de corps organisés, pour les porter dans la mer, que les vagues de celles-ci n'en prennent sur tout le pourtour des deux Amériques; et l'on sait, par de journaliers exemples, que des végétaux apportés par ce fleuve, des rives du Missouri dans le golfe du Mexique, vont attérir sur les côtés d'Islande, et même du Spitzberg." —*De la Chronologie des Terrains et du Synchronisme des Formations.* 1845.

20. CARBONIFEROUS SYSTEM OF NORTH AMERICA.—In North America, the carboniferous system is largely developed, and has been ably illustrated by Professors Silliman, Eaton, Hitchcock, and other American geologists. The stone-coal, or *anthracite*, of Pennsylvania, is associated with conglomerates, sandstones, and argillaceous shale: and the conglomerates are composed of quartz pebbles like those of our Old Red-sandstone. Deposits of anthracite exist in Worcester and in Rhode Island, of which an admirable account has been published by Professor Silliman.

Extensive coal-fields are found to the west of the Alleghany mountains, towards the Mississippi; and the base of the whole extent of the plain of that mighty river appears to be carboniferous limestone, which extends under the Alleghany mountains on the east, and the sand plains on the west, and rests on the granitic rocks of Canada on the north. The uppermost layer of the mountain limestone supports strata of bituminous coal and shale. Iron-stone abounds in these deposits, and mines of lead occur over a district of two hundred square miles, between the Missouri and the Illinois.* The principal coal-fields in the United States are the Appalachian, the Illinois, and the Michigan; the Appalachian is 720 miles long, and, in many parts, 180 wide: that of the Illinois is nearly as large as England in extent.

The Appalachian coal-field, before its original limits were reduced by denudation, is computed, by Mr. Lyell, to have been 900 miles long and 200 wide. The thickness of the carboniferous strata in Virginia and Western Pennsylvania exceeds 3,000 feet.† A large portion of the coal is in the state of *anthracite*, or stone-coal, resulting from the influence of high temperature. For the most, the bituminous coal is that which is farthest removed from the axis of the greatest disturbance, and where the strata have

* Smart's Travels in the United States.

† Professor H. D. Rogers' Address, May 1844.

suffered the least displacement. In the coal-fields where the boldest flexures of the Appalachian chain occur, and the strata have actually been overturned, as near Pottsville, the coal is invariably changed into anthracite.*

The carboniferous system of the United States presents all the essential characters of that of England : the same remarkable phenomenon of the prevalence of *Stigmariæ* in the underclay of the coal-beds, occurs as constantly as in the European coal-fields. Thus in the coal-mines of Blossberg, Pennsylvania, the underclays contain Stigmariæ with their rootlets extending in all directions, as in the underclays of the Welsh coal-measures 3,000 miles distant. At Pottsville, where the coal strata are vertical and worked in the open air, the same phenomenon appears. "Several of the coal seams, ten feet thick, having been removed, a void space was left, and in the wall on one side, corresponding to the roof, were shales full of ferns, lepidodendra, calamites, &c.; while the other side of the trench was formed of the underclay, abounding in stigmariæ. These phenomena lead to conclusions respecting the origin of coal from plants not drifted, but growing on the spot."† But throughout some of the beds of underclay, leaves of fern are plentifully dispersed, though the stigmariæ are apparently imbedded in their natural position.‡ As in Europe, the marine shells and corals so abundant in the limestone, seldom appear in the coal ; but Mr. Lyell observed a bed of black bituminous shale, ten or twelve feet thick, full of marine shells, interstratified with the coal, at Frostburg.§

21. ORGANIC REMAINS OF THE CARBONIFEROUS SYSTEM.—The fossils entombed in these deposits comprise

* See the section of the country between the Atlantic and the Mississippi, through the Alleghanies; Mr. Lyell's Travels in America, p. 92; and the admirable geological map of the United States, in the same work.

† Ibid. pp. 62, 85. ‡ Ibid. p. 18. § Ibid. p. 19.

numerous genera and species. The animal remains are principally found in the calcareous and arenaceous strata, and are referable to zoophytes, mollusca, radiaria, crustacea, and fishes: but few, if any, undoubted relics of any of the higher orders have been discovered. The vegetable fossils, besides constituting the entire mass of the coal, anthracite, &c. are thickly interspersed in the shales, grits, and other intervening deposits. The shells are almost exclusively marine, but there are intercalations of fresh-water species in some localities; as, for example, in Coalbrook Dale, and in the carboniferous beds at Burdie House, near Edinburgh, which consist of limestone and indurated clays, with fresh-water shells, crustaceans, and sauroid fishes, associated with terrestrial plants. These appear to be interpolations between the marine deposits, and were probably formed in an estuary communicating with a river of considerable extent.* In the coal measures of several parts of the central counties of England, around Shrewsbury for instance, there are likewise beds of fresh-water limestones.

But the grand features of the carboniferous system are the immense accumulations of the early vegetation of our globe, presenting to us, in the most legible and striking characters, the peculiar flora of the remote epoch in which these deposits were produced. To obtain any satisfactory results from an examination of these remains, some knowledge of the internal structure of vegetables is requisite; for in a fossil state many of the external characters are, for the most part, so imperfect or obliterated, as to afford but obscure indications of the nature of the original. As in our investigations of the fossil remains of animals, we availed ourselves of the principles of comparative anatomy to reconstruct those extinct forms of being, in like manner

* Dr. Samuel Hibbert, "On the Fresh-water Limestones of Burdie House, near Edinburgh." Edinb. Phil. Trans. vol. xiii.

we must now call to our aid that branch of science which treats of vegetable organization; we shall thus be enabled to restore anew the forests of extinct palms and tree-ferns, the groves of coniferæ, and all the luxuriant vegetation which flourished during the carboniferous epoch. I must, however, restrict myself to a brief enunciation of a few leading botanical principles.* The works of M. Adolphe Brongniart,† and of Messrs. Lindley and Hutton,‡ should be consulted by those who would pursue this attractive department of natural history.§

22. ORGANIZATION OF VEGETABLES.—In the previous discourse, the complex organization of the higher orders of animal existence was remarked; the structure of vegetables, on the contrary, presents a remarkable simplicity. While in most animals each separate function is effected by an organ of peculiar construction, in plants a few tissues, variously modified, constitute the mechanism by which all the vegetable functions are performed. The section of any living plant shows that its intimate structure is made up of cells or vessels.|| This organization is differently arranged in the grand classes of the vegetable kingdom. In the most

* I have still further abridged this article in the present edition, having fully entered upon the subject in my Medals of Creation, vol. i. chap. 4.

† Histoire des Végētaux Fossiles, ou Recherches Botaniques et Géologiques, &c. par M. Adolphe Brongniart. 1 vol. 4to. with numerous plates.

‡ The Fossil Flora of Great Britain, by Dr. Lindley and W. Hutton, Esq. 8vo.

§ See also Henslow's Principles of Physiological Botany; a very instructive and delightful volume.

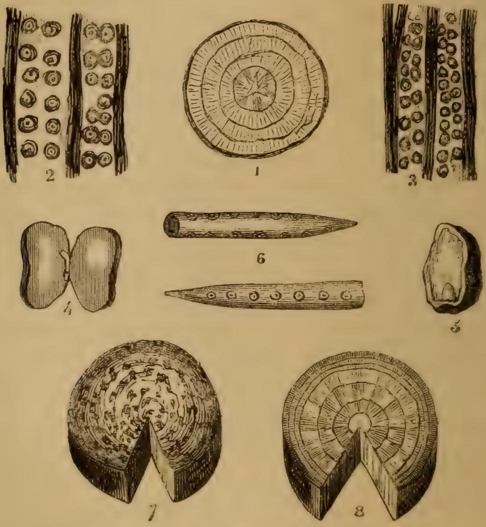
|| Every vegetable cell is the result of the development of a minute granular body, on the surface of which a transparent vesicle arises, and spreads out so as to form a cell, which afterwards expanding more in particular parts, acquires the peculiar form which characterizes the texture to be fabricated. The chemical composition of this elementary structure is identical with starch. In every vegetable, whether the oak or the fungus, this primitive membrane presents the

simple group, the *cellulares*, called also the *acotyledones*, from the absence of *cotyledons*, or seed-lobes, the tissue is wholly cellular, the cells being nearly of equal size and consistence; mosses, lichens, sea-weeds, fungi, &c., are examples (*ante*, p. 601). These plants have no flowers, and hence are named *cryptogamia*. The vegetables belonging to the other great class are termed *vasculares*, from their cellular tissue being more complex, and assuming the structure of tubes and vessels; and *phanerogamic*, from their bearing flowers. Their tissue is composed of cells of various sizes and forms, and of straight and spiral tubes. This class is subdivided into two families, viz. the *monocotyledonous*, so named from the seed having but one fleshy lobe, or *cotyledon* (*Lign*. 154, *fig*. 5), as the onion, lily, &c., and which are also called *endogenous*, (*from within*), because increase takes place from the innermost part of the stem; and the *dicotyledonous*, whose seeds have two lobes (*fig*. 4), as the bean, almond, &c.; these are likewise termed *exogenous*, from the new matter being added externally to the old layers, and thus forming annual circles of increase, as in the oak, elm, &c. (*fig*. 8). A transverse section of the monocotyledonous stems, (as the cane, palm, &c.) presents, therefore, openings of tubes, which are condensed towards the outer surface (*fig*. 7); while that of the dicotyledonous exhibits annular lines of growth with diverging rays, and a central pith (*fig*. 8); the latter character is of peculiar importance, because all the other classes are destitute of a central cellular column.

In some groups of dicotyledonous trees the elongated cells, or tubes, are studded with ducts or glands (*fig*. 6), and this is particularly the case in the woody fibres of the *Coniferæ*, or *cone-bearing* trees; so called from the fruit being in the form of a cone, as in the pine, fir, &c.; transverse sections of the stems show the concentric layers and radiated struc-

same character; and all the beautiful and apparently complicated tissues of vegetables, are but modifications and expansions of these simple elementary nuclei or vesicles.

ture peculiar to the dicotyledonous class. In this magnified view of a slice of the common fir (*fig.* 2), the glands are seen to be arranged in double parallel lines. In a remarkable family of pines, the *Araucariæ*, these bodies are



LIGN. 154.—ILLUSTRATIONS OF VEGETABLE STRUCTURE.

Fig. 1. Section of a coniferous tree, showing the concentric and radiated structure.
2. Longitudinal section of a fragment of pine-wood, magnified to exhibit the spotted vessels.
3. Longitudinal section of two vessels of an Araucaria, magnified to show the glands arranged alternately.
4. A dicotyledonous seed split open; the germ is seen in the middle.
5. Section of a monocotyledonous seed, with the germ below.
6. Dotted tubes of coniferous wood.
7. Transverse section of a monocotyledonous stem.
8. Transverse section of a dicotyledonous tree, showing concentric circles, medullary rays, and the central pith.

placed alternately, and sometimes in triple rows. All the trees of this order secrete resin, have branched trunks, and linear, rigid, entire leaves: species are found in the coldest as well as in the hottest regions. The *Araucaria* is a native of Norfolk Island, a small spot in the South Pacific, about fifteen miles in circumference. This island presents a scene of the most luxuriant vegetation, and abounds in this particular group of pines, some of which attain a height of two hundred feet, and a circumference of thirty.

Even in the foliage of the plants of the different families, there are such obvious distinctive characters, that the botanist can often, from a mere fragment of a leaf, detect the dicotyledonous structure in the fibrous interlacing of its vessels, as in that of the oak; and the monocotyledonous, in the smooth parallel veins in that of the lily. The application of these principles to the investigation of the fossil remains of vegetables we may now consider.

23. Climate and Seasons indicated by Fossil Wood. —In the course of these Lectures, it has been demonstrated how, by a knowledge of comparative anatomy, the form, structure, and economy of beings long since obliterated from the face of the earth, may with certainty be determined; in like manner, by the aid derived from a few botanical principles, we may not only discover the form and character of vegetables, of which but the faintest vestiges remain, but also point out important inferences relating to the state of the earth, the nature of the climate, and even of the seasons which prevailed at the periods when those plants flourished. Our distinguished countryman, Professor Babbage, has admirably exemplified the inductive process by which such results may be obtained:—

"We have seen, that dicotyledonous trees increase in size by the deposition of an additional layer annually between the wood and the bark; and that a transverse section of such trees presents the appearance of a series of nearly concentric, irregular rings, the number of which indicates the age of the tree. The relative thickness of these annular markings depends on the more or less flourishing state of the plant during the years in which they were formed. Each ring may, in some trees, be observed to be subdivided into others, thus indicating successive periods of the same year during which its vegetation was advanced or checked. These rings are disturbed in certain parts by irregularities resulting from branches; and the year in which each branch first sprang from the parent stock, may therefore be ascertained by proper sections. These prominent effects are obvious to our senses; but every shower that falls, every change of temperature that occurs, and every wind that blows, leaves on the vegetable world the traces of its passage; slight, indeed, and imperceptible perhaps to us, but not the less permanently recorded in the depths of those woody fabrics.

"All these indications of the growth of the living tree are preserved in the fossil trunk, and with them also frequently the history of its partial decay. Let us now examine the use we can make of these details relative to individual trees, when considering forests submerged by seas, imbedded in peat mosses, or transformed, as in some of the harder strata, into stone. Let us imagine that we possessed sections of the trunks of a considerable number of trees, such as those occurring in the stratum called the *Dirt-bed* in the Island of Portland (*ante*, p. 386). If we were to select a number of trees of about the same size, we should possibly find many of them to have been contemporaries. This fact would be rendered probable if we observed, as we doubtless should do, on examining the annual rings, that some of them, conspicuous for their size, occurred at the same distances of years in several trees. If, for example, we found on several trees a remarkably large annual ring, followed at the distance of seven years by a remarkably thin ring, and this again, after two years, succeeded by another large ring, we should reasonably infer from these trees, that seven years after a season highly favourable to their growth, there had occurred a season unfavourable to them: and that after two more years, another very favourable season had happened, and that all the trees so observed had existed at the same period of time. The nature of the season, whether hot or cold, wet or dry, would be known with some degree of probability, from the class of tree under examination. This kind of evidence, though slight at first, receives additional and great confirmation by the discovery of every new ring which supports it; and, by a considerable concurrence of such observations, the succession of seasons might be ascertained in geological periods, however minute."

24. MICROSCOPIC EXAMINATION OF FOSSIL TREES.*—The discovery of a process by which the structure of fossil vegetables can be examined with as much facility as that of recent plants, has shed an unexpected light on the ancient botany of our planet. On this plate of glass you perceive a thin film of a dark substance, apparently of varnish. It is a slice of the blackest jet, and if held

* Medals of Creation, vol. i. p. 76.

between the eye and the light, appears of a rich brown colour, and displays a ligneous structure, resembling that of deal or fir; it is, in fact, a thin section of fossil coniferous wood; for jet is nothing more than the wood of some species of fir or pine, that has undergone the process of bituminization, as I shall presently explain. When viewed under a microscope, the small glands, which I have mentioned as peculiar to the *Coniferæ* (*Lign.* 154, *fig.* 23), are distinctly visible. The other specimens before us are silicified woods, prepared in the same manner. A few words, in explanation of the mode by which sections of such extreme thinness are obtained, may not be uninteresting. A slice is first cut from the fossil wood by the usual process of the lapidary; one surface is ground perfectly flat, and polished, and then cemented to a piece of plate glass by means of Canada balsam; the slice thus firmly attached to the glass is next ground down to the requisite degree of tenuity, so as to permit its structure to be seen by the aid of the microscope. It is by this ingenious process that the intricate structure of any fossil plant can now be investigated, and the nature of the original determined, with as much accuracy as if it were living.*

25. NATURE OF COAL.—In this stage of our inquiry, the nature of the process by which vegetables are converted into the mineral substance termed *Coal*, requires additional consideration. When sections of coal, obtained by the method above described, are examined under the microscope, the fine reticulated structure of the tree or plant whence it was derived, is distinctly visible; and often the cells are filled with a light amber-coloured matter of a bituminous nature, and so volatile as to be readily expelled by heat before the texture of the coal is destroyed.†

* See Observations on Fossil Vegetables, by Henry Witham, Esq. F.G.S. 1 vol. 4to. With plates of the internal structure of fossil plants.

† Mr. Hutton, on "Coal."

The ducts or glands on the vessels of the coniferæ may often be detected, on the recently exposed surface of a block of coal without any preparation whatever. Even in the ashes of coal, after incineration, the spiral vessels frequently remain uninjured, and form interesting microscopical objects; and in the anthracite, or stone-coal of America, which is a hard slate rock, the vascular tissue may be rendered distinctly visible.*

Mr. Parkinson, whose work abounds in interesting observations and experiments on the fossilization of vegetable substances, has shown that the formation of coal has depended upon a change, which all vegetable matter undergoes when exposed to heat and moisture, under circumstances that exclude the air, and prevent the escape of the more volatile principles.† In this condition, a fermentation, which he terms the bituminous, takes place, of which the phenomenon exhibited by *mow-burnt hay* is a familiar example. The production of sugar, and, by continuance of the process, of vinegar, is effected by vegetable fermentation in the open air. In the process of hay-making, the

* A method has lately been discovered by Dr. Franz Schulz, by which the internal vegetable structure may be more readily detected in lignite, coal, anthracite, &c., than by any other previously known. It consists in treating the coal to be examined with nitric acid in a platinum vessel, and then evaporating the acid by a moderate heat, and igniting the residue till no further empyreumatic vapours are given off; the residue is submitted to the action of nitric acid, and the ignition repeated. Thus prepared, the coal is placed in a platinum crucible with a lid perforated in the centre, and air is blown from a gasometer through the aperture in the lid, while the crucible is kept at a red heat over a spirit-lamp, so that the coal is slowly consumed. The ash thus obtained is not in the state of coke, as would be the case in the ordinary method of incineration, but forms a brown powder full of white splinters. These splinters, on microscopical examination, are found to be the siliceous cellular structure of the original vegetable. By this process vegetable tissue has been detected in the *anthracite*, or stone-coal of Pennsylvania, by Dr. Baily.—See *American Journal of Science*, vol. i. 2d series, p. 124. January, 1846.

† Organic Remains of a Former World, vol. i. p. 181.

saccharine fermentation is induced, and the grass acquires a peculiar fragrance and sweetness; but in wet seasons, when the hay is prematurely heaped together, the volatile principles cannot escape from the inner mass of vegetable matter, heat is rapidly evolved, a dense vapour exhales, and at length flames break forth, and the stack is consumed. When the process is interrupted, and combustion prevented, the hay is found to have acquired a dark-brown colour, a glazed or oily surface, and a bituminous odour. Were vegetable substances, under the circumstances here described, placed beneath great pressure, so as to confine the gaseous principles, bitumen, lignite, or coal, might be produced, according to the various modifications of the process. Mr. Parkinson thus traces vegetable matter through every stage of the saccharine, vinous, acetous, and bituminous fermentations; producing alcohol, ether, naphtha, petroleum, bitumen, amber, and even the diamond; and explains that by the process of bituminization, stems and branches have been converted into brown coal, lignite, jet, coal, and anthracite.

26. Liebig on the formation of Coal.—The nature of these changes is thus explained by the eminent chemist, Baron Liebig. Vegetable substances after death undergo two processes of decomposition; namely—

1st. *Fermentation* or *decay*, which is as low process of combustion, in which the combustible parts of a plant unite with the oxygen of the atmosphere; for the decay of woody fibre in contact with air or oxygen, converts the latter into an equal volume of carbonic acid; the presence of water and a certain temperature being necessary. Woody fibre in a state of decay forms *humus*.

2dly. *Mouldering* or *putrefaction* of wood subjected to the action of water, and more or less excluded from the air. When pure ligneous fibre, as linen, for example, is placed in contact with water, considerable heat is evolved, and the vegetable matter loses its coherence, and becomes a soft friable mass; in short, it undergoes a true putrefaction.

When all access to air is excluded and consequent oxidation and a removal of a certain quantity of hydrogen, then other changes ensue, and true mineral coal containing combustible oils is the result. In deposits of wood-coal changes are still going on, as is proved by the issue from clefts in the rocks of the coal formation, of inflammable gases; as carburetted hydrogen, nitrogen, and olefiant gas. Thus from the continual removal of oxygen in the form of carbonic acid, from layers of wood-coal, that substance gradually approaches in its composition to mineral coal. From the latter hydrogen is disengaged in the form of a compound of hydro-carbon; and the removal of all the hydrogen forms *anthracite* or stone-coal.*

The chemical changes of this nature which are continually taking place in carboniferous deposits, give rise to those evolutions of carburetted hydrogen, or *fire-damp*, which are frequently so fatal to the miners. And it is a fact worthy of remark, as corroborative of the opinions above advanced, that the bituminous quality of the coal depends on the nature of the bed which immediately covers it. If this be argillaceous shale the escape of the gaseous matter of the coal is prevented; but if the roof be arenaceous, the gas is evolved from the coal, and collects in the innumerable fissures and pores of the sandstone, which become filled with carburetted hydrogen, and form as it were a gasometer, ready to explode upon any occasion. Mr. Hutton is of opinion that this gas exists in a highly condensed, and even liquid state in the pores of the coal; and that the small explosions (termed by the miners eructations) which often take place when the coal is struck with a pick, are due to the sudden expansion of the condensed gas.†

According to the analysis of Dr. Thompson, the best Newcastle coal consists of—Carbon, 75.28; Hydrogen, 4.18; Oxygen, 4.58; Nitrogen, 15.96.

Iron and copper pyrites abound in many of the beds of coal; and indeed, these metallic substances are very generally met with in accumulations of carbonized vegetables. The carburetted hydrogen, with the acid and extractive

* Liebig's Chemistry, translated by Professor Playfair.

† Sir H. De la Beche, Geological Manual, 3d edit.

matter, resulting from vegetable decomposition, are adequate to produce copper pyrites, and even metallic copper from water holding salts of copper in solution. The pyrites or copperas, as it is termed, so abundant in the Wealden strata of the Isle of Wight, has originated from this cause.

27. Bitumen, Petroleum, Naphtha.—The changes effected in vegetable matter during its conversion into coal, also give rise to various bituminous productions. *Mineral oil* is an inflammable fluid which often occurs in carboniferous deposits, sometimes forming powerful springs. *Naphtha* is another liquid of this nature, which is nearly colourless, and transparent, burns with a blue flame, emits a strong odour, and leaves no residuum. In driving a level through coal shale in Derbyshire, springs of naphtha burst forth, and covered the surface of the water in the level; and having been accidentally set on fire by the approach of a candle, formed a burning spring, which continued some weeks.

Petroleum is of a dark colour, and thicker than common tar; in the carboniferous strata of Coalbrook Dale, and in some parts of Asia, this substance rises from coal-beds in immense quantities. From a careful analysis of petroleum, and certain turpentine oils, it is clear that their principal component parts are identical; and it therefore appears evident that petroleum has originated from the coniferous trees, whose remains have contributed so largely to the formation of coal; and that the mineral oil is nothing more than the turpentine oil of the pines of former ages—not only the wood, but also large accumulations of the needle-like leaves of the pines may have contributed to this process. We thus have the satisfaction of obtaining, after the lapse of thousands of years, information as to the more intimate composition of those ancient forests of the period of the great coal formation, whose comparison with the present vegetation of our globe is a subject of so much interest. The mineral oil may be ranked with amber, succinite, and other similar bodies which occur in the strata. The springs of petroleum do not seem to depend on combustion, as has been supposed, but to be simply the effect of subterranean heat. According to the information we now possess, it is not necessary that strata should be at a very great depth beneath the surface to acquire a temperature equal to the boiling point of water, or mineral oil. In such a position the oil must have suffered a slow distillation, and have found its way to the surface; or have so impregnated a portion of the earth, as to form springs or wells, as in various parts of Persia and India.*

Bitumen is an inspissated mineral oil, of a dark brown colour, with a strong odour of tar. In the Odin mine of Derbyshire, a species occurs which is elastic, being of the consistence of thick jelly, and bearing some resemblance to soft India-rubber; as it will remove the traces of a pencil, it has been named mineral caoutchouc. Some bitumens possess the colour and transparency of amber: the soft varieties may be rendered solid by heat.

From these bituminous substances, we pass by an easy transition to *Amber*, of which we have already spoken (p. 242), for black amber, both in its appearance and composition, closely resembles the solid bitumens.

A mineral called *mellite*, or honey-stone, from its colour, is found among the bituminous wood of Thuringia, which in its chemical composition, and electrical properties, bears a great analogy to amber; it is usually crystallized in small octahedrons.†

28. THE DIAMOND.—The chemical constituents of the substances above described are chiefly carbon and hydrogen, with a small proportion of oxygen, the essential elements of vegetable matter. But the *Diamond* is pure carbon; at a heat less than the melting point of silver, it burns, and is volatilized, yielding the same elementary products as

* Dr. Reichenbach.

† Organic Remains of a former World, vol. i. pl. i. fig. 2.

charcoal. Sir Isaac Newton remarked, that the refractive power, that is, the property of bending the rays of light, was three times greater in respect of their densities, in amber and in the diamond, than in other bodies; and he therefore concluded that the diamond was some unctuous substance that had crystallized.

Sir David Brewster observed, that the globules of air (or some fluid of low refractive power) occasionally seen in diamonds, have communicated, by expansion, a polarizing structure to the parts in immediate contact with the air-bubble, a phenomenon which also occurs in amber. This is displayed in four sectors of polarized light encircling the globule of air; a similar structure can be produced artificially, either in glass or gelatinous masses, by a compressing force propagated circularly from a point. This cannot have been the result of crystallization, but must have arisen from the expansion exerted by the included air on the amber and the diamond, when they were in so soft a state as to be susceptible of compression from a very small force; hence Sir David Brewster concludes that, like amber, the diamond has originated from the consolidation of vegetable matter, which has gradually acquired a crystalline form by the slow action of corpuscular forces.*

Liebig concurs in the opinion that the diamond is of vegetable origin, and offers the following remarks on its probable mode of formation.

"If we suppose decay to proceed in a liquid containing carbon and hydrogen, then a compound with still more carbon must result, in a manner similar to the production of the crystalline colourless *naphthalin* from a gaseous compound of carbon and hydrogen. And if the compound thus formed were itself to undergo further decay, the final result must be the separation of carbon in a crystalline form. Science can point to no process capable of accounting for the origin and formation of diamonds, except that

* Geolog. Trans. vol. iii. p. 459.

of decay. Diamonds cannot have been produced by the action of fire; for a high temperature and the presence of oxygen gas, would call into play their combustibility. But there is the greatest reason to believe that they have been formed in the humid way—that is, in a liquid; and the process of decay is the only cause to which their formation can with probability be ascribed."*

The matrix of the diamonds of Southern India is the sandstone breccia of the clay-slate formation. Captain Franklin discovered in Bundel Kund, diamonds imbedded in sandstone, which he supposed to be the same as the New Red-sandstone, for there were at least 400 feet of that rock below the lowest diamond beds, and strong indications of coal underlying the whole mass.†

29. ANTHRACITE, PLUMBAGO, &c.—The coal commonly used for domestic purposes in this country is the bituminous, containing, as previously stated, a volatile inflammable fluid in its cellular structure. The *Anthracite*,‡ culm, or stone-coal, is coal deprived of its bitumen, by the causes already explained. When coal is in contact with trap, or basalt, it is often in the state of anthracite; while the layers in immediate contact with the volcanic rocks are charred, and in some instances, the mass is converted into *plumbago*, or *graphite*; the substance used for drawing-pencils. By a series of interesting experiments, that eminent chemist and geologist, Dr. Macculloch, demonstrated the transitional changes from bitumen to plumbago. Hydrogen predominates in the fluid bitumen; bitumen and carbon in coal; in anthracite bitumen is altogether wanting; and in plumbago, the hydrogen has also disappeared, and carbon only or chiefly remains.

In America, from the prevalence of anthracite in the carboniferous deposits, this substance is in universal use;

* Liebig's Chemistry, vol. i. p. 336.

† London and Edinburgh Journal, October, 1835.

‡ The name is derived from a Greek word, signifying coal.

but in England it is seldom employed except in the furnaces of our manufactories. This kind of coal is however largely developed in many districts ; and the anthracite of South Wales extends from the Vale of Neath on the east, to St. Bride's Bay on the west. Some of this coal is in the state of charcoal, and requires a degree of heat of 531° Fahrenheit, for its ignition ; but when ignited, it burns with a bright flame, and is the most durable of fuel.

30. Petrifaction of Vegetables.—As in the sandstones and other strata, the stems of trees and plants are often found, not in the state of coal, but converted into stone—in some instances calcareous, in others siliceous—I shall in this place offer a few remarks in illustration of the process by which such a change has been effected.

In true petrifactions a transmutation of the parts of an organized body into mineral matter takes place. Patrin, Brongniart, and other philosophers, suppose that petrifaction has frequently been effected suddenly, by the combination of gaseous fluids with the constituent principles of organic structure. It appears, indeed, certain, that the conversion of animal and vegetable substances into silex, must, in many instances, have been almost instantaneous, for the most delicate parts, those which would undergo decomposition with the greatest rapidity, are preserved. The fact of the silicification of trees in loose sand, and of the soft bodies of mollusca in their shells, as in the fossil oysters found in the chalk at Brighton,* while neither the sand nor the shells are impregnated with silex, cannot be explained by the infiltration of a siliceous fluid into cavities left by the decomposition and removal of the animal substance. Von Buch has shown that the silicifying process never immediately attacks the calcareous shell, but developes itself only upon the organic matter, and that where this substance is not present, no silicification

* Medals of Creation, p. 363.

takes place. A combination of gaseous fluids with the constituent principles of the animal or vegetable substances, changing the latter into stone, without modifying the arrangement of the molecules so as to alter the external form, seems the only mode by which such transmutations can have been effected. The production of congelation, by a simple abstraction of caloric, is akin to this change; but petrifaction is induced by the introduction of another principle. As to density, the most subtile gas may acquire the greatest solidity; as, for example, in the union of oxygen with metallic substances.

The following observations of Mr. Stokes,* on fossil wood partly petrified by carbonate of lime, throw light on this subject. The specimen which gave rise to these remarks was a piece of beech-wood, from a Roman aqueduct in Germany, in which were several insulated portions, converted into carbonate of lime, while the remainder was unchanged. "Sometimes," observes Mr. Stokes, "the most minute structure is preserved, as in the vessels of palms and coniferæ, which are as distinct in the fossil as in the recent trees. From this state of perfection, we have every degree of change, to the last stage of decay: the condition of the wood, therefore, had no influence on the process. The hardest wood, and the most tender and succulent, as for instance, the young leaves of the palm, are alike silicified. In some instances, the cellular tissue has been petrified, and the vessels have disappeared; here silicification must have taken place soon after the wood was exposed to the action of moisture, because the cellular structure would soon decay; the process was then suspended, and the vessels decomposed. In other examples, the vessels alone remain; a proof that petrifaction did not commence till the cellular tissue was destroyed. The specimens where both cells and vessels are silicified, show

* Transactions of the Geological Society, vol. v. p. 207.

that the process began at an early period, and continued till the whole vegetable structure was transmuted into stone."

My lamented friend, the late Dr. Turner, in some admirable comments on the subject of petrifaction, remarked, that whenever the decomposition of an organic body has begun, the elements into which it is resolved are in a condition peculiarly favourable to their entering into new combinations; and that if water, charged with mineral matter, come in contact with bodies in this state, a mutual action takes place, new combinations result, and solid particles are precipitated, so as to occupy the place left vacant by the decomposed organic substance.

31. Artificial Vegetable Petrifactions.—M. Göppert has published the result of an interesting investigation of the condition of fossil plants, and the process of petrifaction. Layers of ironstone nodules, as we have previously stated, are common in the carboniferous strata. They appear to have once constituted continuous layers, the nodules having been produced by segregation, *i. e.* the substance of which they are composed has separated from the constituent parts of the rock after deposition.* The first segregation often appears to have been caused by the presence of some extraneous matter, sometimes a trilobite, or a shell, and very commonly the leaf of a fern.† Mr. Parkinson had remarked, that the leaves in these nodules might sometimes be separated in the form of a carbonaceous film; and M. Göppert having found similar examples, was induced to undertake a set of experiments. He placed fern-leaves in clay, dried them in the shade, exposed them to a red heat, and obtained striking resemblances to the fossil plants. According to the degree of heat, the plant was found to be either brown, shining black, or entirely lost, the impression only remaining; but in the latter case the surrounding clay

* Sir H. De la Beche, Researches in Theoretical Geology, p. 96.

† Medals of Creation, p. 81.

was stained black, thus indicating that the colour of the coal shales is from the carbon derived from the plants they include. Plants soaked in a solution of sulphate of iron were dried and heated till every trace of organic matter had disappeared, and the oxide was found to present the form of the plant. In a slice of pine-tree the punctured vessels peculiar to this family of vegetables were perceptible. These results by heat are probably produced naturally, by the action of moisture under great pressure, and the influence of a high temperature.

32. Silicification, or petrifaction of vegetables by silex.—The various forms in which silex is found, are proved to have been dependent on its state of solution; in quartz crystals it was entirely dissolved; in agate and chalcedony it was in a gelatinous state, assuming a spheroidal, or orbicular disposition, according to the motion given to its molecules. Its condition appears also to have been modified by the influence of organic matter. In some polished slices of flints from Bognor, the transition from flint to agate, chalcedony, and crystallized quartz, is beautifully exhibited. The shell of an echinus, in my possession, is transmuted into crystallized carbonate of lime, while the lower portion of the cavity is occupied by flint, on which is a layer of crystals of calcareous spar. The curious fact, that the shells of the echinites in the chalk are almost invariably filled with flint, while the crustaceous covering is converted into calcareous spar, is, perhaps, attributable to the animal matter having undergone silicification; for the most organized parts are those which appear to have been most susceptible of siliceous petrifaction. In a specimen in my collection, the oyster itself is turned into flint, while the shell is, as usual, carbonate of lime.* The shells of mollusca, the crustaceous skeletons of echinoderms, and the guards of the belemnites, appear to have possessed too

* Medals of Creation, p. 363.

large a proportion of calcareous earth, to be silicified; they seem to have been changed into spar, by water charged with carbonic acid gas having insensibly effected the crystallization of their molecules.*

Some specimens of silicified wood, collected from the interior of Australia, by Sir T. Mitchell, and recently transmitted to the British Museum, are entirely permeated by silex; but on the external surface of these stems, there are some circular spots of chalcedony, that appear to have originated from the exudation of the liquid silex from the interior, in viscid globules distended with air, which burst, collapsed, and became solidified in their present form.

That silicification is induced under circumstances connected with a high temperature, we have a remarkable instance in the petrified wood observed in Kerguelen Island, by Captain Sir James Ross. Seams of coal, varying in thickness from a few inches to four feet, are imbedded in trap rock; and numerous fossil trees were found lying under a bed of shale, which was covered by a mass of basalt several hundred feet thick. Some portions of the wood were so little altered that it was necessary to take them in the hand to be convinced of their fossil state; and the wood was found passing from that condition into charcoal which would burn freely; while other portions were so completely silicified as to scratch glass.† In fact, the permeation of vegetable tissues, by aqueous solutions of silex of a high temperature, appears to be the necessary condition under which silicification takes place.‡

* See an interesting Essay on this subject, by M. Alexandre Brongniart, "*Essai sur les Orbicules Silicieux, &c.*" Paris, 1831.

† Voyage of Discovery in the Southern and Antarctic Regions, in 1839-43.

‡ The experiments and observations on the structure of plants, by my friend, Mr. Reade, afford some interesting facts in illustration of this subject. Mr. Reade states that "by the agency of heat the surrounding siliceous matter may be liquefied, and the carbon and

33. FOSSIL PLANTS OF THE COAL.—I proceed to the examination of the flora of the carboniferous epoch. The layers of pure coal, as we have already stated, are wholly composed of carbonized vegetables; and when we consider that these beds are from ten to thirty feet in thickness, and in some instances amount even to sixty feet,* it

gaseous products of the wood dispelled, while the essential characters of the fibrous and cellular structure are undisturbed. The unconsumed portions, which alone constitute the true vegetable frame-work, are thus, as it were, mounted in the fluid silica. This property of vegetable fibre, of retaining its form, notwithstanding the action of a high temperature, suggested to me the probability of detecting structure in the ashes of coal; and upon examination, I found that the white ashes of 'slaty coal' furnish most beautiful examples of vegetable remains." In a subsequent paper the author adds the following remarks:—"Having ascertained that the siliceous organization of recent plants is not destructible, even under the blow-pipe, it appeared to me a natural inference, that the less intense heat of a common fire would not destroy this siliceous tissue in the coal-plants; and my opinion has been confirmed, for I have detected in the white ashes of coal all the usual forms of vegetable structure, viz. cellular tissue, smooth and spiral fibre, and annular ducts. A comparison of the ashes of coal with those of recent plants, would doubtless afford some further insight into the nature of fossil vegetables. To mention only one instance—I have ascertained that the lumps of carbonized matter, which occur abundantly in the upper sandstone near the Spa at Scarborough, are, in al probability, portions of the stems of some arundinaceous or gramineous plants. The structure of the epidermis is precisely similar to that of the oat, consisting of parallel columns, set with fine teeth, dove-tailing, as it were, into each other, while the underlying tissue consists of cubical cells, a thin horizontal section exhibiting a series of squares. From these facts it is evident, that the true framework and basis of vegetable structure in the plants of coal, is not only entirely independent of carbon, but that it has also resisted the bituminous decomposition, which has converted all the carbonaceous materials into a highly inflammable substance."—*Rev. J. B. Reade, F.R.S. on the Structure of the solid materials found in the Ashes of Recent and Fossil Plants.*—Journal of Science, vol. ii. p. 413.

* In England, the thickest bed of coal, amounting to thirty feet, is in the Dudley basin. In Poland, there is a continuous mass of coal, sixty feet thick.—*Sir R. Murchison.*

seems difficult to account for such an immense accumulation of wood, and plants, and foliage, as would be required to produce so enormous an amount of carbon, without any intermixture of earthy detritus. Nor is it possible to conceive that such beds could have been formed by the successive submersion of a region covered with vegetation. The shales above the coal are highly charged with carbonaceous matter, and contain a profusion of leaves and stems. The vegetable remains are always in a carbonized state; but the leaves sometimes possess such a degree of tenacity and elasticity as to be separable from the stone. The leaves and seed-vessels which occur in the iron-stone nodules have, in many instances, undergone a metallic impregnation, as is often the case in specimens from Coalbrook Dale. Brilliant sulphuret of iron, or pyrites, in some examples, permeates the entire vegetable tissue; in others, the stems and leaflets are replaced by white hydrate, or sulphate of alumina; and in many, by crystals of galena, or sulphuret of lead, and of blende or sulphuret of zinc. In the sandstones, the stems have generally a carbonaceous crust, and their internal structure is sometimes found in a calcareous, and occasionally in a silicified state.

The coal plants which have been accurately determined amount to nearly a thousand species, of which two-thirds are related to the ferns, and the higher tribes of the cryptogamia; the remainder consist of coniferæ, and a few flowering monocotyledonous and dicotyledonous trees.* But numerous species are undescribed, and new forms are continually being discovered.

* M. Adolphe Brongniart, in an interesting memoir on the genus *Nöggerathia* (*Ann. des Sciences Naturelles,* Janvier, 1846) states, that according to the present state of fossil botany, the terrestrial vegetation of the earth, at the carboniferous epoch, was limited to two of the grand divisions of the vegetable kingdom, namely, *"les Cryptogames acrogènes ou Vasculaires, et les Phanérogames dicotylédones gymnospermes."*

The British species exceed 200;* I will place before you a few of the predominant forms, which will serve to convey a general idea of the nature of the carboniferous flora; for the greater number of the plants that are found in the British coal-mines also occur in Europe, America, Australia, and even Greenland.† The coal-field on the shores of Lake Breton contains plants identical with that of Newcastle, though 3,000 miles distant.‡

Such was, and is, generally the received opinion; but it is probable that more extended observations will modify this conclusion; for already an accurate investigation of but a few specimens of fossil plants from the coal formation of Australia, proves that the ancient flora of that country differs essentially from that of Europe; and no traces have been observed of those remarkable and abundant genera which are characteristic of the European and American coal-fields—such as Sigillaria, Calamites, and Lepidodendron.§

34. EQUISETACEOUS PLANTS. — The stems of several gigantic plants allied to the *Equisetum fluviatile*, or Mare's-tail of our marsh lands, are very abundant in the coal measures. While the recent species seldom exceed two feet in height, and half an inch, or an inch in diameter, the fossil stems often attain twenty or thirty feet in height, and fourteen inches in diameter. The *Equisetum columnare*, is a common species both in the carboniferous strata, and in the oolite; and in both formations is occasionally found in an erect position.‖

* See Mr. Tennant's useful little volume, entitled, A Stratigraphical List of British Fossils, London, 1847.

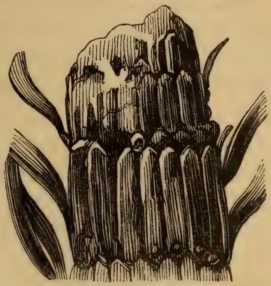
† Prodrome d'une Histoire des Végétaux Fossiles, par M. Adolphe Brongniart.

‡ Mr. Lyell's Travels in America.

§ See Mr. Morris on the Fossil Flora of Australia, in M. de Strzelicki's New South Wales.

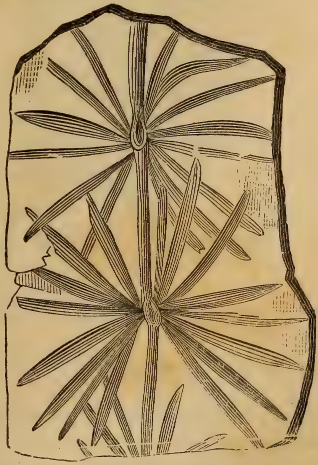
‖ See Medals of Creation, p. 108.

Calamites. The plants of this extinct genus, closely resemble the Marestail, but are destitute of the encircling sheaths, and are uniformly striated longitudinally. They are often forty feet long, and three feet in diameter, and are so abundant in the coal, as to prove that they constituted an important feature in the flora of the countries of the carboniferous epoch.* Calamites have also been found in strata below the coal, and belong to the most ancient terrestrial vegetation of which any traces have been discovered. A fragment of a small stem, with leaves, is represented in *Lign.* 155.



LIGN. 155.—CALAMITES CANNÆFORMIS; from Coalbrook Dale.

Asterophyllites. Plants with verticillate leaves are common in the coal-shales; they have been named *Asterophyllites*, or Star-leaf. Some of them resemble the foliage of Equisetum or Hippuris, but no certain conclusions have been obtained as to the nature of the originals. Two of the usual forms are here represented (*Lign.* 156 and 158, *fig.* 1). They are often associated with seed-vessels, which occur in



LIGN. 156.—ASTEROPHYLLITES EQUISETIFORMIS; from Coalbrook Dale.

* Medals of Creation, p. 110.

groups of from five to twenty, and were evidently didymous, that is, grew in pairs.*

35. FOSSIL FERNS.—The *Brake* or fern of our commons and waste lands, is a familiar example of a remarkable and numerous family of plants, distinguished by the peculiar distribution of their seed-vessels. The arborescent ferns rise into trees from thirty to forty feet in height, their stems being marked with scars from the decay of the leaf-stalks, and their summits covered with an elegant canopy of foliage; their general appearance is shown in this sketch (*Lign.* 167, *fig.* 5). The leaves of the herbaceous species are very elegant, and present great variety in their forms, and in the mode in which the veins of the

1 2

LIGN. 157.—FROM THE CARBONIFEROUS STRATA AT BURDIE-HOUSE. p. 693.

Fig. 1. Sphenopteris linearis.
— 2. ———— affinis.

leaf are disposed; from the character of the latter, M. Adolphe Brongniart has established the generic distinctions of the fossil plants of this family. The beautiful state in which these remains occur in the coal shale, is shown in the

* Medals of Creation, p. 153, Lign. 34.

specimens before us (*Lign.* 157, 158). The fructification on the back of the leaf is sometimes preserved.

The stems, with their elliptical cicatrices, or scars, bear some resemblance to those of the palms, but are readily distinguished, from their longest diameter being vertical, while in the palms it is transverse: sections of the stems of these two tribes have also distinctive characters.* The

1. 2.

LIGN. 158.—FROM COALBROOK DALE.
Fig. 1. Asterophyllites Parkinsoni.
— 2. Pecopteris Mantelli.

large tree-ferns are confined almost exclusively within the tropics; humidity and heat being the conditions most favourable to their development. In the coal, there are not less than 150 species of ferns, nearly all of which belong to the tribe of *Polypodiaceæ;* the common *Polypody*, so frequent on old walls, will convey an idea of the characters of their foliage. The fossil species present great variety and elegance in the

LIGN. 159.—PECOPTERIS ADANTOIDES, from Coalbrook Dale.

* Végétaux Fossiles, tom. i. pl. 37.

form and disposition of the fronds and pinnules. The *Pecopteris*, a genus containing fifteen British species, is found every where (*Lign.* 158, 159).*

LIGN. 160.—SIGILLARIÆ, AND FERN, FROM THE COAL-MEASURES.

(One-fourth the natural size.)

Fig. 1. Sigillaria Voltzii, from the anthracite of Baden; *a* the external surface; *b* the inner surface, a portion of the outer bark being removed.
— 2. Sigillaria Sillimani: from the coal-mines of Pennsylvania.
— 3. Pecopteris Miltoni; a specimen showing the young frond coiled up like a crosier.

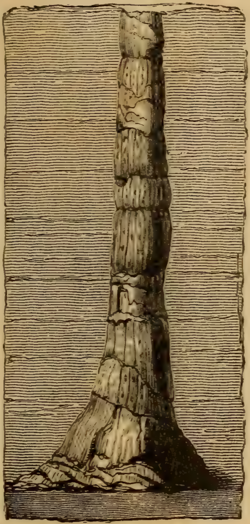
36. SIGILLARIA.—Among the most common and striking objects that arrest the attention of a person who visits a coal-mine for the first time, and examines the fossil remains profusely scattered around him, are long flat narrow slabs of a coaly substance, having the surface fluted longitudinally, and uniformly ornamented with rows of deeply imprinted symmetrical figures, disposed with great regularity. These relics are the flattened stems, covered by the bark or rind, of trees of large size: the markings on the surface being the scars left by the separation of the petioles or leaf-stalks.† The name *Sigillaria* has been

* See Medals of Creation, pp. 111—129, for figures and descriptions of fossil ferns.

† The markings left on a cabbage-stalk by the removal of the leaves are of a similar nature.

given to these extinct trees, from the impressions appearing as if made by a seal or die. These stems are generally found broken to pieces, and when lying in a horizontal position in the strata, are quite flat from the pressure of the superincumbent deposits.

The stems vary from a few inches to three feet in circumference, and specimens have been discovered that indicate a length of sixty feet. They often escape compression, and stand perpendicularly, intersecting the horizontal strata, and having roots proceeding from the base. They are generally surrounded by an envelope, an inch in thickness, of fine, crystalline, bituminous coal. The longitudinal plaitings, which are the characteristic marks of the Sigillariæ, are commonly indistinct at the base. A specimen figured in the beautiful and highly interesting work of Dr. Lindley and Mr. Hutton,* was ten feet high (*Lign.* 161), and two feet in diameter at the base. Its roots were in shale, immediately above the main bed of coal, and the trunk extended through several strata of shale and sandstone.



Lign. 161.—Stem of Sigillaria pachyderma; in the Jarrow Coal. *Ten feet high.*

The upright stems almost always consist of sandstone within the carbonized bark; but one silicified specimen has been discovered, by which M. Ad. Brongniart has been

* The Fossil Flora of Great Britain.

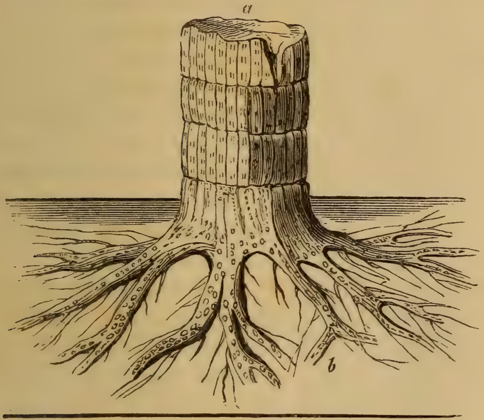
enabled to ascertain the relations of these remarkable extinct trees with recent forms. From this examination it results that the Sigillariæ were a family of coniferous trees, belonging to the great division of gymnospermous dicotyledons. In their external form they must have somewhat resembled the Cacteæ, or Euphorbiæ, but were more nearly related by their internal organization to the Zamiæ and Cycadeæ.* Their leaves and fruits are unknown, for no certain connexion has yet been established between these stems and the foliage and fruit with which they are collocated.†

37. STIGMARIA.—The fossil vegetables known under this name, which are so abundant in the underclay of the coal-beds, have long excited the curiosity of collectors, and set at defiance all attempts to determine their botanical characters, until recent discoveries proved the correctness of M. Adolphe Brongniart's conjecture, that they were the roots of Sigillariæ. These bodies are of a cylindrical form, from a few inches to several feet in length, and are often ten or twelve inches in circumference. The surface is covered with oval or circular depressions with a small tubercle in the middle, disposed in quincunx order. When broken across, a small cylindrical axis or core is found to extend longitudinally throughout the stem, like a medullary column. When observed in the underclay, long tapering fibres or rootlets are found attached to the tubercles of the pits with which the surface is covered; and these are sometimes several feet in length. The internal structure of the *Stigmariæ* presents a ligneous zone resembling that of the

* The stems of some of the Sigillariæ, when uncompressed, remind one of the longitudinally furrowed cylindrical columns of the *Pilocereus senilis,* which grow so luxuriantly, and many feet in height, in Real del Monte, in Mexico. There are fine living specimens of this form of Pilocereus, in the Royal Botanic Gardens, at Kew.

† See Medals of Creation, p. 135.

Sigillariæ, except that the ring of medullary tissue possessed by the latter, is wanting; a difference, as M. Brongniart remarks, precisely similar to that existing between the stems or branches of a dicotyledonous tree, in which the woody cylinder is associated internally with bundles of

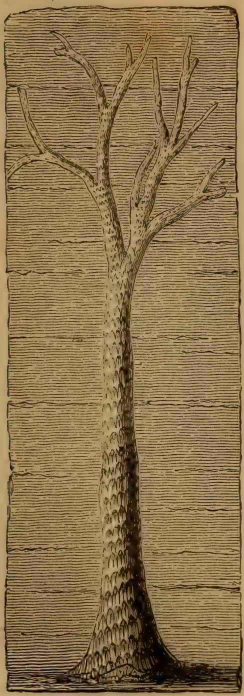


Lign. 162.—Stem and roots of a Sigillaria; in a Coal mine, near Liverpool.

a, The trunk traversing a bed of coal.
b, The roots (*Stigmariæ*) spreading out in the underclay.

medullary tissue, but the roots of the same tree are destitute of them. This opinion, long since advanced by the eminent French savant, was confirmed about four years ago, by Mr. Binney's discovery in the coal strata at St. Helen's near Liverpool, of an upright stem of a Sigillaria, nine feet high, with ten roots several feet long attached, and extending in the underclay in their natural position (as shown in *Lign.* 162); *and these roots proved to be undoubted Stigmariæ.*

In the floor of the Victoria mine, at Dunkinfold near Manchester, at the depth of 1100 feet from the surface, Mr. Binney discovered a magnificent specimen of Sigillaria, which exhibited on its stem the respective characters of three supposed species (*S. pachyderma*, *reniformis*, and *organum*), and had stigmaria-roots, which were traced twenty feet.*



LIGN. 163.—LEPIDODENDRON STERNBERGII.

A fossil tree, thirteen and a half feet wide at the base, and thirty-nine feet high.

This figure, from the Fossil Flora of Great Britain, (Pl. CCIII.) represents a specimen discovered in the Bensham coal seam, in the Jarrow coal-field.

In the Sydney coal-field, at Cape Breton, several upright stems of Sigillariæ, having roots that are undoubted stigmariæ, have been discovered; and in the Pictou coal, in Nova Scotia, the same fact has been noticed, and communicated to the Geological Society of London.

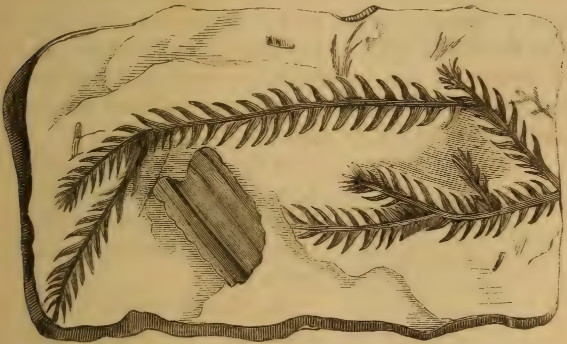
As there is considerable variety in the form and disposition of the tubercles of the Stigmariæ, it is probable that some of them may be the roots of other trees of the carboniferous deposits, with the stems of which they are associated.†

38. LEPIDODENDRON.—This is a tribe of plants which has largely contributed to the formation of the coal-strata, and whose remains rival in number and magnitude the Calamites and Sigillariæ. The name, which signifies

* Over the door of the room containing the fossil vegetables in the British Museum, there is a Stigmaria twenty-six feet long, with numerous rootlets.

† Medals of Creation, p. 142.

Scaly-tree, is derived from the imbricated appearance of the surface of the stem, occasioned by the form and arrangement of the little angular imprints or scars left by the removal of the leaf-stalks. Some of these trees have been found almost entire, from their roots to the topmost branches; as in the example here figured (*Lign.* 163), which was nearly forty feet in height. The foliage consists of simple linear leaves, which are spirally arranged around the stem, and appear to have been shed from the base of the tree with age. The markings produced by the attachment of the leaves are never obliterated. In their structure, external configuration, mode of ramification, and disposition



LIGN. 164.—LYCOPODITES BENETTIÆ,* FROM THE TYROL.

(*Drawn from nature, by Miss Ellen Duppa*)

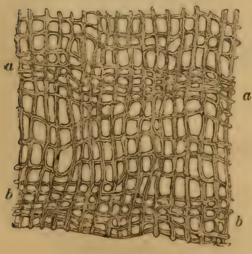
of the leaves, these trees accord closely with the *Lycopodiaceæ,* or Club-mosses. These are small herbaceous plants,

* I have named this elegant plant in honour of the late Miss Etheldred Benett, of Norton House, Wilts; a lady, whose liberal contributions of specimens, and instructive observations on the chalk fossils of Wiltshire, afforded me important assistance in my early attempts to investigate the organic remains of Sussex.

inhabiting woods and bogs; their leaves are simple and imbricated, that is, lie over each other like scales. Most of them trail on the ground, but a few species are erect; the tropical forms, which are the largest, do not exceed three feet in height. But notwithstanding this disparity in size, M. Brongniart has shown that the Lepidodendra must be regarded as gigantic plants of this family. They were, in fact, arborescent Lycopodiaceæ, comparable in size to the largest pines, and formed extensive forests during the carboniferous epoch, beneath whose shade flourished the lesser ferns and associated plants.

The fruit of the living Club-mosses is an oval or cylindrical cone, which in some species forms an imbricated spike at the extremity of the branches; and there are numerous fossil fruits of this kind collocated with the stems and leaves of the Lepidodendra, and in some instances attached to the branches; they have received the name of *Lepidostrobi*, or scaly-cones.*

A beautiful example of a fossil Lycopodium, from a tertiary formation in the Tyrol (*Lign.* 164), closely resembles the recent club-mosses.



LIGN. 165.—Transverse section of a portion of the stem of a recent Pine (*Pinus strobus*), highly magnified.
a, *b*, Portions of concentric annu al layers.

39. CONIFEROUS TREES AND PLANTS.—It was formerly supposed that no vestiges of coniferous plants and trees, which occur so abundantly in the secondary formations, were present in the coal; but Mr. Witham, by microscopical examination, ascertained that trees of this type constituted no inconsiderable portion of the flora of the carboniferous epoch; and remains

* Medals of Creation, p. 149, Lign. 31.

of this order have since been detected in every formation of later origin. The recent coniferæ are arborescent, dividing into numerous branches, which are disposed in most genera with considerable regularity. The transverse sections exhibit concentric annual lines of growth (as in *Lign.* 165), and the vertical show the sides of the vessels studded with little ducts (*Lign.* 166).

Lign. 166.—Longitudinal section of pine-wood, parallel to a medullary ray; showing the rows of ducts.

Some of the fossil trees resemble the European pines in their internal structure: but the greater number belong to the Araucarian type, which is characterized by the rows of glands being disposed, when double, not side by side, as in *Lign.* 166, but alternately, as we have previously explained (p. 696).*

The pine-trees of the coal have but few and slight appearances of the lines by which the annual layers are separated, and resemble in this respect the existing species of tropical regions; we may therefore infer that the seasons of the countries where the coal-plants flourished were subject to but little diversity, and that the changes of temperature were not abrupt.†

In a quarry at Craigleith, near Edinburgh, at a depth of 140 feet, part of the trunk of a very large coniferous tree was discovered: its length was thirty-six feet, and the circumference of the base nine feet. Polished sections of this stem beautifully display the coniferous structure. A tree fifty-nine feet long, traversing twelve beds of sandstone, has since been exposed; and as is commonly the case, the

* In the Royal Gardens at Kew, there are several flourishing trees of the *A. excelsa*, and other kinds of Araucariæ.

† Mr. Witham.

bark was carbonized, and the woody stem was in some parts in the state of sandstone, and in others silicified. The remains of Cycadeous plants have likewise been detected in the coal.*

40. Flora of the Coal.—A more extended notice of the fossil plants of the carboniferous system is not within the scope of these Lectures, and we will now take a brief review of the principal facts that have been submitted to our notice. We have seen that the most remarkable character of the flora of that remote epoch, is the immense numerical ascendance of the vascular, or higher tribes of cryptogamic plants, which amount to two-thirds of the whole of the species hitherto determined. With these are associated a few palms, coniferæ, and cycadeæ, and dicotyledonous plants approaching to the cacteæ, and euphorbiaceæ. The vast preponderance and magnitude of the vegetables bearing an analogy to the tribes of *ductulosæ*, but differing from existing species and genera, constitute, therefore, the most important botanical feature. Thus we have plants related to the Equisetum (*Calamites*), eighteen inches in circumference, and from thirty to forty feet high; tree-ferns (*Sigillariæ*) fifty feet in height; and arborescent club-mosses (*Lepidodendra*) attaining an altitude of sixty or seventy feet. The contrast which such a flora presents to that afforded by the woods and forests of dicotyledonous trees, and the verdant turf, which now grow on the surface of the carboniferous districts of England, is as striking as the discrepancy between the zoology of the palæozoic formations, and that of the present day. This restoration of

* The fossil plants, named by M. Brongniart *Nöggerathia*, are referred to the family of the Cycadeæ by this eminent observer, from there having been found associated with these stems, leaves with nervation like certain living American *Zamiæ*, and others of a special form resembling those which bear the fruit in *Cycas revoluta*; and also grains or fruits strikingly analogous to those of the Cycas.

some of the vegetable forms which flourished in the carboniferous era, will perhaps prove more illustrative of this phenomenon than mere description (*Lign.* 167).

1 2 3 4 5 6 7 8 9

LIGN. 167.—THE FLORA OF THE CARBONIFEROUS EPOCH.

(*Designed and drawn by Miss Ellen Maria Mantell.*)

Fig. 1. Araucaria. 2. Asterophyllites. 3. Pandanus. 4. Equisetum. 5. Arborescent fern. 6. Fern. 7. Calamites. 8. Lepidodendron. 9. Sphenopteris.

To arrive at any satisfactory conclusions as to the nature of the countries which supported the plants of the coal, we must consider the geographical distribution of the related existing genera, and the circumstances which conduce to their full development. It is well known that a hot climate, humid atmosphere, and the unvarying temperature of the sea, are the circumstances which exert the most favourable influence on the growth of Ferns and other cryptogamic plants; low islands in tropical latitudes being the localities where these forms of vegetation flourish most luxuriantly. But must we therefore infer that the countries in which the carbonaceous flora grew were groups of islands enjoying an intertropical climate?—In the paucity of the gramineæ or grasses, which form so large a proportion of the existing floras, and the predominance of ferns, the vegetation of the coal-measures approaches that of New Zealand, in which the cellulosæ form one-third of the whole, and the grasses are very few in number.*

41. ATMOSPHERIC CONDITIONS DURING THE CARBONIFEROUS EPOCH.—It is remarkable that amidst the luxuriant vegetation which prevailed on the dry lands during the Carboniferous epoch, there should not have existed contemporaneous herbivorous quadrupeds; but not a relic of any animal of this kind has been discovered in the coal strata. Indeed, with the exception of the Iguanodon of the Wealden (*ante*, p. 423), no remains of large vegetable feeders have been found in any of the deposits anterior to the eocene, in which first appear relics of the herbivorous pachyderms; nor even a vestige of phytophagous terrestrial mollusca.

It was an opinion once very generally entertained, and the idea still seems to find favour,† that previously to and during the carboniferous period, the atmosphere was so charged with carbonic acid gas, as to be unfitted for the respiration of animals of a higher order than reptiles; and that the dense and luxuriant vegetation of that epoch was designed to purify the air, by elaborating coal, and thus abstracting the superabundance of irrespirable gas, and setting free a corresponding proportion of oxygen: thus rendering the surface of the earth suitable for the existence of terrestrial reptiles, and ultimately of birds and mammalia. But Mr. Lyell has clearly shown, not only the fallacy of such surmises, but that, so far as we know, if any

* See Medals of Creation, p. 202.

† See Professor Owen's Hunterian Lectures, vol. ii. p. 15.

change were induced in the constitution of the atmosphere by such an agency, it would be the reverse of that assumed; for an excess of vegetation would tend to diminish the average amount of carbonic acid, and consequently the air must have been purer than in the succeeding epochs.* It is therefore clear that the absence of herbivorous animals cannot be explained by unfavourable atmospheric conditions: and again we may point to New Zealand as a country having a luxuriant vegetation, yet without herbivorous quadrupeds.†

42. Formation of Coal-measures.—From the facts which have passed under our examination, we may now advantageously consider what were the circumstances which gave rise to these prodigious layers of carbonized matter unmixed with other materials—these immense beds of vegetables, from which animal remains are almost wholly excluded;—and whether accumulations of trees and plants, which in after ages shall present phenomena of a like nature, are in progress at the present time?

The manner in which the carboniferous strata have been deposited, has been a fruitful source of discussion among geologists. Some contend that the coal-measures were originally peat-bogs, and that the successive layers were occasioned by repeated subsidences of the land (*ante*, p. 670); others, that the vegetable matter originated from rafts, or drifted forests, like those of the Mississippi, which floated out to sea, and there became engulfed;—others suppose that they were formed in vast inland seas or lakes, the materials of the successive beds being brought down by periodical land-floods: and the supporters of each hypothesis adduce numerous facts in corroboration of their respective opinions. There can be no doubt that coal may

* Mr. Lyell's Travels in America, vol. i. p. 152.

† The only indigenous mammalia in New Zealand is one species of *Rat*, and *Bat*; and there are no large reptiles whatever.

be, and has been, formed under each of these conditions; and that at different periods, and in different localities, all these causes have been in operation; in some instances singly, and in others in combination. That some of the isolated basins of coal may be carbonized peat-bogs is not improbable, considering that peat often occurs in beds, including trees in an erect position, and extending over extensive tracts of country; and in modern peat-bogs (*ante*, p. 66), layers are found having the conchoidal fracture and lustrous appearance of coal: but no traces of the plants which most largely contribute to modern peat formations, as the *Sphagnum*, have been observed in the ancient carboniferous deposits.

Other coal-measures may have been accumulated in fresh-water lakes, or in estuaries, as for example those of Burdie House, and some of the Derbyshire and Yorkshire deposits, where the coal is associated with lacustrine shells and crustaceans: and the Shrewsbury coal-field, in which are beds of limestone several feet thick, abounding in cyprides and fresh-water shells.*

But the carboniferous strata spread over vast areas, and containing intercalations of sandstones, and limestones, with marine remains in abundance, like those of Russia (*ante*, p. 690), must have been deposited in the sea. The fact that some beds of pure coal are from thirty to sixty feet in thickness, seems inexplicable, except by the drifting of immense masses of vegetable matter—whole forests—into the abyss of the ocean, or into the basin of an inland sea.

The occasional erect position of the stems, and the preservation of delicate leaves, do not invalidate this inference; for in the rafts formed by the entangled floating forests of the American rivers, trunks of trees frequently occur upright; and my distinguished friend, Admiral Sir Edward Codrington, informed me that in the interior of

* Silurian System, p. 84.

these rafts, grasses and tender plants are often found entire. Such masses, therefore, might be drifted many hundred miles, and yet the imbedded fragile species, protected by the external network of entangled branches, remain uninjured; and, undergoing bituminization, while enveloped by the soft mud permeating the mass, might become changed into durable forms, like those which abound in the natural herbaria of the coal-measures. That the conversion of vegetable matter into coal would take place under such conditions we may readily conceive, from what has been advanced in the course of this argument.

43. Coal-measures from submerged lands.—The theory so ably advocated by Mr. Lyell, and other eminent geologists, of the formation of coal-measures from repeated submergences and elevations of lands covered with dense forests (*ante*, p. 670), seems to be applicable only to those carboniferous formations which are made up of regular alternations of coal with beds composed of such earthy materials, as to render it probable they were once capable of supporting a luxuriant vegetation.

But in many of the examples cited in proof of this hypothesis, the bases and roots of the erect trees are in contact either with a stratum of rock that never could have been vegetable mould, or with a seam of coal a few inches thick; and setting aside the improbability of the bed on which they are supposed to have grown, having afforded the nutriment necessary for the support of such trees, the little depth to which the roots extend, proves that the trunks could not have been broken off at the height of a few feet from the ground, while growing on the spot; for such violence must have rooted them up from the shallow soil, and laid them prostrate. This objection, I think, strongly applies to the examples of upright trees at St. Etienne; to those in Virginia, where the bases of the trees stand on a seam of coal, resting on granite (*ante*, p. 520); and those in the Bay of Fundy, where the roots of the erect trees are in contact with a thin bed of pure coal. It seems probable that in these, and many other instances of a like nature, the verticality of the trunks may have originated simply from the trees having floated with their stems uppermost, in consequence of their roots being loaded with soil. This is a constant occurrence in the great floods of the American rivers; the *snags*, as they are termed, which often render the navigation difficult and perilous, being formed by drifted trees forced into an oblique direction by the current. Trees in an upright position are often carried out to sea, and have been seen far from land, floating with their topmost branches above the water.

But if more extended observations should establish the fact, which the late discoveries have rendered highly probable, namely, that the roots (*Stigmariæ*) of the forest-trees (*Sigillariæ*) of the carboniferous system, are invariably present, and for the most part in their natural position, in the under-clay, and beneath each bed of pure coal (*ante*, p. 667), we then cannot refuse our assent to the conclusion that those trees grew on the areas now occupied by their carbonized remains. Yet may we not inquire, whether these facts will not admit of some other interpretation than that which attributes the phenomena to the effect of alternate subsidence and elevation of the land? May there not have been extensive inland areas, depressed, like the basin of the Caspian, many hundred feet below the level of the sea, and affording the shelter, warmth, and moisture, required by an intertropical flora; and subjected to periodical inundations from mountain torrents, poured down from alpine regions on which the pines and other coniferæ associated with the arborescent ferns of the coal, may have flourished? Would not such physical conditions, modified by occasional changes in the relative level of the land and water by subterranean movements, meet the exigences of the case? We might even carry the speculation further, and suppose these countries to have been depressed to so great a depth as to have been influenced by the radiation of heat from the interior of the earth; and thus there may have existed in temperate regions a local hot climate capable of supporting a tropical flora?* The interest and importance of a satisfactory solution of this problem have led me to extend these remarks to a considerable length; and I offer them as mere suggestions, and with great deference.†

44. ZOOPHYTES AND ECHINODERMS OF THE CARBONIFEROUS SYSTEM.—We must now briefly notice the animal

* The most remarkable known instance of an area of land depressed far below the sea-level, is that mentioned by Baron Humboldt. "In descending eastward from Jerusalem to the Dead Sea, and the Valley of Jordan, a view is enjoyed which, according to our present hypsometric knowledge of the earth's surface, has no parallel in any other region. The rocks on which the traveller treads, with the open sky over his head, are 1388 feet below the level of the Mediterranean."—*Cosmos*, p. 399. *Col. Sabine's Translation.*

† Though from the revolutions which have swept over the earth's surface, and the displacements and mutations which its crust has undergone since the carboniferous epoch, there is but little probability that any of the coal-fields are now in the same position in relation to the sea-level, as at the period of their formation, I would, nevertheless, direct attention to the following statements and remarks of the illustrious philosopher just cited.—"The depth of the Coal-basin at Liege, is estimated by Herr Von Dechen, at 3,809 feet below the surface, and 3,464 feet *beneath the level of the sea;* and that of Mons, at 5,329: while the lowermost coal strata of the Saar-Revier are computed by the same eminent observer to descend to a depth of 21,358 feet *below the sea level,* or 3.6 geographical miles. This is a depth below the sea, equal to that of Chimborazo above it; and the temperature would be 467° of Fahrenheit, if the increase be in the supposed ratio of 1° for every 54 feet of vertical depth (*ante,* p. 34). We have, therefore, from the highest summits of the Himalayahs, to the lowest portions of the basins which contain the fossil flora of the carboniferous epoch, a vertical distance of about 48,000 feet, or $\frac{1}{433}$th of the earth's semi-diameter."—*Cosmos,* pp. 399, 400.

remains entombed in the deposits that are associated with those which have proved so rich and varied a field of botanical research. The Zoophytes and Mollusca are for the most part marine, and in a great measure confined to the limestones below the coal. The Corals amount to many species; and consist of various kinds of *Tubipora*, *Syringopora*, *Catenipora*, *Cyathophyllum*, *Astræa*, *Turbinolia*, &c.

The mountain limestone swarms with Crinoidea, and entire beds are made up of their petrified remains, as was explained in the former Lecture (*ante*, p. 650); and many elegant species of *Actinocrinus*, *Cyathocrinus*, and *Platycrinus*, occur in these deposits.

A singular type of Crinoideans, named *Pentremites* (*Lign*. 168, *fig*. 7), also abounds in the mountain limestone, both in England and America* (*ante*, p. 656).

Echinoderms of a peculiar character (*Echinocrinus*), their shells being formed of hexagonal plates, (and not pentagonal as in the Cidares,) have been discovered in the carboniferous limestone of Ireland and Russia. A species of Cidaris (*C. Phillipsii*), with large mammillated tubercles and muricated spines, occurs in the Yorkshire limestone, and is the earliest known geological appearance of this family.

45. Shells of the Carboniferous System. — The remains of nearly 300 species of the various tribes of mollusca have been obtained from this formation. Foraminiferous shells—*Rotaliæ*, *Textilariæ*, *Fusulinæ*—have been detected in slices of the Yorkshire limestone by a microscopical examination; and in Russia the upper beds of the mountain limestone in the Lower Volga, consist of laminated calcareous shales composed of an aggregation of the shells of a minute species of Fusulina (*F. cylindrica*), resembling grains of wheat, and allied to the *Nonioninæ*.†

* Medals of Creation, vol. i. p. 327.

† Geology of Russia, Pl. I. fig. 1.

Freshwater bivalve shells, comprising about ten fluviatile species, occur in some of the coal-measures, forming regular layers of limestone, called by the miners *mussel-bands*, from the shells (*Uniones*), of which they are chiefly composed. The marine tribes are in a great measure confined to the limestone below the coal. But in Yorkshire, Professor Phillips has discovered a remarkable exception; in the coal-measures of that county, there is a thin layer of marine shells, intercalated between freshwater strata.

Many species of simple spiral univalves abound in some of the limestones; and one genus, *Euomphalus* (*Lign.* 168, *fig.* 5), is remarkable, from the inner volutions being traversed by imperforate septa.*

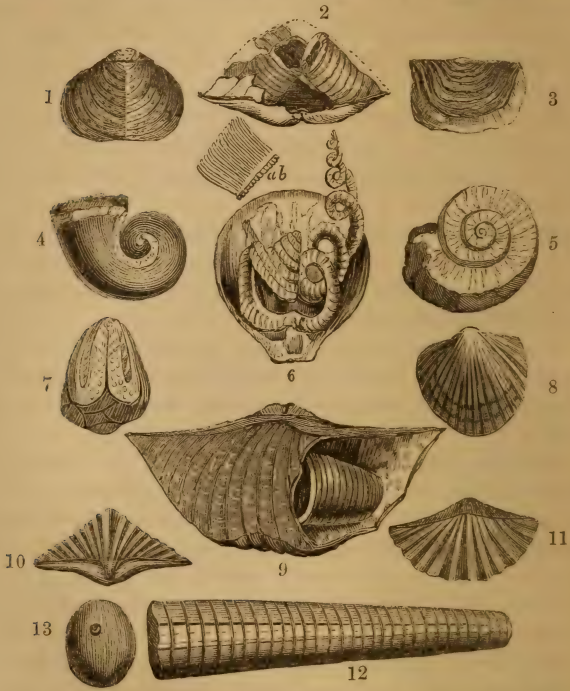
Numerous bivalves of existing genera of mollusca also occur; and the *Pecten*, or scallop, first appears in this system in great numbers, comprising upwards of seventy species.

But the most striking modification in the molluscous fauna, is the abundance of those extinct types of brachiopoda (*ante*, p. 564), the *Spirifers*, *Leptænæ*, &c. of which we first obtained a glimpse in the Permian system. These occur in profusion, and entire beds of the mountain limestone are conglomerates formed of the shells of these remarkable animals.

Spirifers. As we descend to the more ancient rocks, we shall find these fossils yet more prevalent: and I will, therefore, in this place offer a few remarks on the structure of this family of mollusca. The small subglobular bivalves (*Terebratulæ*) so abundant in the chalk, are sometimes found empty, and if the valves be carefully separated, two curious appendages are seen projecting from the hinge into the interior of the shell; these processes are the internal skeleton for the support of the organs of respiration.† In the *Spirifers*

* Medals of Creation, p. 426. † Ibid. p. 378.

(*Lign.* 168, *figs.* 2, 6, 9, 10, 11,) there are two spiral appendages (hence the name of the genus) which are closely



Lign. 168.—Shells and Crinoidea from the Palæozoic strata.

Mountain limestone. *Fig.* 1. Leptæna punctata. 2. Spirifer trigonalis. 4. Cast of Bellerophon cornu-arietis. 5. Euomphalus pentangulatus. 7. Pentremites ellipticus. 9. Spirifer trigonalis, showing one of the spiral processes *in situ*. 10. Spirifer triangularis. 12. Orthoceratite. 13. Septum of the same.
Wenlock limestone. *Fig.* 3. Leptæna depressa. 11. Spirifer octoplicatus.
Oolite. *Fig.* 8. Terebratula affinis; this figure was introduced by mistake.
Recent shells. *Fig.* 6. Terebratula psittacea, showing the fringed spiral brachia, and one of them extended; the perforated valve, and the lobe of the mantle being removed. *Fig. a b*, a portion of the ciliary fringe magnified.

coiled, and are often, like the substance of the shell itself, changed into calcareous spar, (*figs.* 2, 9); in specimens where the shell is removed, these organs may be seen in their original situation.

The following description, by Professor Owen, of a recent animal of the same family, a native of the South Seas, explains the nature of this structure.

"The loop-like processes observable in the interior of the shells of many of the fossil terebratulæ, are the internal skeleton, and are for the attachment of the muscular stems of the arms. In *Terebratula psittacea,** a recent species (*Lign.* 168, *fig.* 6), two spiral arms, fringed at their outer margins, are seen to arise from these processes; these arms are quite free, except at their origins: when unfolded, they are twice as long as the shell, and in a state of contraction are disposed in six or seven spiral gyrations, which decrease towards their extremities. The mechanism by which the arms are extended is most beautiful and simple: the stems are hollow from one end to the other, and filled with fluid, which being acted upon by the spirally disposed muscles composing the walls of the canal, is forcibly injected towards the extremity of the arms, which are thus unfolded and protruded. The spiral disposition of the arms is common to the whole of the brachiopodous genera, whose organization has hitherto been examined; and it is therefore probable, that in the fossil genus Spirifer, the entire brachia were similarly disposed, and that the internal, calcareous, spiral appendages were their supports. If indeed the *brachia* of Terebratula psittacea had been so sustained, the species would have presented in a fossil state an internal structure very similar to that of Spirifer."†

Cephalopoda.—The cephalopodous shells found in the mountain limestone and associated strata, amount to upwards of sixty species; the Ammonites of this system are of a peculiar kind (*Goniatites*, Medals, p. 494). There are several species of *Bellerophon* (*Lign.* 168, *fig.* 4),

* In the Mediterranean, at the depth of 100 fathoms, there is a profusion of one living species of Terabratula; and also a species of *Orthis*, which is one of the most ancient generic types of brachiopoda, several species occurring low down in the Silurian deposits. In the collection of shells in the British Museum, there is a slab of stone with some twenty or thirty recent Terebratulæ attached, from New Holland.

† Professor Owen, on the Anatomy of the Brachiopoda; Zoological Transactions, vol. i. p 145.

which is a shell without septa, like that of the Argonaut: and of the *Orthoceras* (*Lign.* 168, *fig.* 12), which may be described as a straight Nautilus, of an elongated, cylindrical shape, tapering to the extremity, and having entire septa, pierced by a siphunculus (*fig.* 13). The Orthoceratites are often from twenty to thirty inches in circumference at the largest extremity.*

46. CRUSTACEANS AND INSECTS.—With the layers of fresh-water shells that are intercalated in some of the coal deposits, there are a few species of the fluviatile crustaceans, the *Cyprides*, so abundant in the Wealden and tertiary lacustrine limestones. Cyprides occur in the Shrewsbury, and Burdie House strata, and in the latter, two species of a branchiopodous crustacean (*Eurypterus*, Medals, p. 541,) one of which is twelve inches long, have been discovered by Dr. Hibbert.

LIGN. 169.—LIMULUS FROM COALBROOK DALE.
(*Limulus trilobitoides.*)

In the ironstone nodules of Coalbrook Dale, the remains of small crustaceans sometimes form the nucleus, and are in a good state of preservation. Some of these crustaceans are referable to the *Limulus*, or King-crab; a genus which is abundant in the seas of India and America. The Limulus has a distinct carapace or buckler, and the last segment is prolonged into a style; it has two eyes in front of the shield, and the gills are disposed on lamelliform processes. A beautiful specimen of a fossil Limulus from Coalbrook Dale is here figured (*Lign.* 169).†

* Medals of Creation, p. 484.

† The chemical changes which have taken place in the carboniferous strata, and led to the formation of the bands and nodules of

It is in the carboniferous system that we first meet, in a descending order, with vestiges of the extinct family of crustaceans called Trilobites (*Medals*, p. 552): but as these animals are especially characteristic of the older rocks —the Silurian—I shall reserve a particular notice of them for the next discourse.

Insects.—The remains of insects belonging to several genera have been found; from the ironstone nodules of Coalbrook Dale, several species of beetles, related to the *Curculio*, or diamond beetle, have been obtained. In a nodule from the same locality I discovered the wing of a large neuropterous insect, closely resembling a species of living Corydalis of Carolina.*

iron-stone, are thus explained by Sir H. De la Beche:—"The argillaceous iron-stones are formed of carbonate of iron, mingled mechanically with earthy matter, commonly corresponding with that constituting the shales with which they are associated. Mr. Hunt, of the Museum of Economic Geology, instituted a series of experiments to illustrate the production of these clay ironstones, and he found that decomposing vegetable matter prevented the further oxidation of the protosalts of iron, and converted the peroxide into protoxide of iron, by taking a portion of its oxygen to form carbonic acid. Under the conditions necessary for the production of the coal distributed among the sand, silt, and mud, the decomposition of the vegetable matter would necessarily form carbonic acid, among other products. This carbonic acid, mixed with water, would spread with it over areas of different dimensions according to circumstances; forming salts and meeting with the protoxide of iron in solution, it would unite with the protoxide, and form a carbonate of iron. The carbonate of iron in solution would mingle with any fine detritus which might be held in mechanical suspension in the same water; and hence, when the conditions for its deposit arose, which would happen when the needful excess of carbonic acid was removed, the carbonate of iron would be thrown down intermingled with the mud; and if not in sufficient quantity to form continuous layers, would aggregate into nodules, and be arranged in planes amid the sediment."—*Memoirs of the Geological Survey of Great Britain*, p. 185.

* Medals of Creation, p. 578. This specimen is now in the British Museum.

Fossil Scorpion.—Not only are the remains of insects imbedded in the coal strata, but also those of animals, to which they served as food. A fossil *Scorpion* has been discovered by Count Sternberg, in carboniferous argillaceous schist, at Chomle, S.W. of Prague, in Bohemia.* This fossil is about two inches and a half long, and is imbedded in coal shale, with leaves and fruits. The legs, claws, jaws and teeth, skin, hairs, and even portions of the trachea, or breathing apparatus, are preserved. It has twelve eyes, and all the sockets remain ; one of the small eyes, and the left large eye, retain their form, and have the cornea, or outer skin, preserved in a corrugated or shrivelled state. The horny covering is also preserved ; it is neither carbonized nor decomposed, the peculiar substance of which it consists, *elytrine*, having resisted decomposition and mineralization.

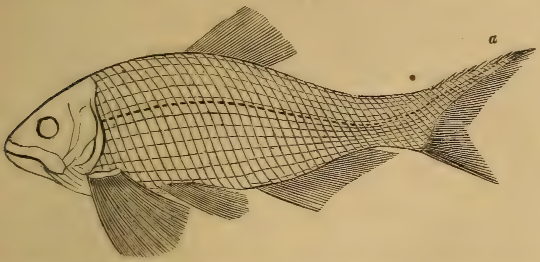
47. FISHES OF THE CARBONIFEROUS SYSTEM.—With the exception of some enigmatical footmarks, and the specimen of a reptile said to have been recently procured from the coal strata of Saarbrück, fishes are the only vertebrata of which any relics have been observed either in the carboniferous system, or in any fossiliferous deposits of higher antiquity.

The fishes of the coal, with but one exception, are of the placoid and ganoid orders (*ante*, p. 340) : and several of the genera have not been found in any other system ; all of these have the heterocercal form of tail (*ante*, p. 530). I can only allude to a few of the most characteristic.

Amblypterus. This is a genus restricted to the carboniferous system, charactererized, as its name implies, by very large and wide fins composed of numerous rays. The scales are rhomboidal and finely enamelled ; and the teeth are small, numerous, and set close together like the hairs of a brush ; indicating that these fishes fed on decayed sea-

* See Dr. Buckland's Bridgwater Essay, plate 46, p. 406, *et seq.*

weeds and soft animal substances. The tail is a good example of the heterocercal type, a restored outline of the



LIGN. 170.—RESTORED FIGURE OF THE AMBLYPTERUS; A FISH PECULIAR TO THE CARBONIFEROUS SYSTEM: *one-sixth the nat. size.*

(*By M. Agassiz.*)

a, The upper lobe of the tail, into which the vertebral column is prolonged.

fish is given in *Lign.* 170. Four species have been found in nodules of ironstone at Saarbrück, in Lorraine; and at Newhaven, near Leith.

Megalichthys.—Of the remarkable group of fishes termed *Sauroid*, the remains of two genera have been discovered in the strata at Burdie House by Dr. Hibbert, and subsequently in several other localities. The *Megalichthys* is covered with enamelled, smooth, quadrangular scales, very thick, and nearly an inch wide. The head is protected by strong enamelled plates. The large teeth are striated hollow cones. This fish was from three to four feet in length.

Holoptychius.—This is a genus of gigantic sauroid fishes, some species of which attained a length of thirty feet. The scales are thin and nearly circular, the upper surface corrugated in ridges, and from one to five inches in diameter. The plates covering the head have a shagreen surface with irregular ridges. It has large conical sauroid teeth of great density; and numerous long slender teeth.

Carcharopsis.—By this name M. Agassiz distinguishes a fish of the shark family, resembling the Carchariodonts (*Medals*, p. 621, *fig.* 3), of which teeth have been found in the carboniferous deposits of Yorkshire and Armagh in Ireland. These teeth are compressed, triangular, and crenated on the edges, with large plaits or folds on the enamelled surface towards the base of the crown. These are the only relics of fishes belonging to this tribe of sharks, that have been discovered in strata below the tertiary.

48. Reptiles of the Carboniferous epoch.—Allusion has already been made to the quadrupedal footprints supposed to be those of batrachians, on argillaceous sandstone, low down in the coal measures of Pennsylvania. The specimens collected by Mr. Lyell, and now in his possession, appear to me undoubted impressions of this kind (*ante*, p. 566). Other examples have been obtained from the same place by Dr. King and other American geologists. These, and the recent discovery of a considerable portion of the skeleton of a saurian reptile in the coal strata of Saarbrück, afford the most ancient indications of the existence of any terrestrial vertebrated animals : and they are likewise the sole vestiges of any creature that crawled or walked upon the surface of the lands that were clothed with the luxuriant vegetation of the carboniferous flora.

49. Climate of the Palæozoic ages. — The cause of the difference between the natural climates now prevailing over extensive zones of the earth's surface, and those which the organic remains discovered in the strata lead us to conclude have formerly subsisted during very long periods of time—and apparently over the greater part of its whole extent—is one of those geological problems, the solution of which is not at present within our reach. Unable to account for so extraordinary a distribution of a high climatorial temperature — a diffusion of heat and light so

utterly at variance with that which has prevailed during the human epoch—the mind naturally endeavours to penetrate the mystery by a reference to physical causes extraneous to our planet. But, as yet, astronomy has afforded no satisfactory elucidation of the subject.

A variation in the eccentricity of the earth's orbit, and a change in the position of the tropical zone, from the precession of the equinox—both changes, which though extremely slow, are appreciable—have been brought forward to account for the phenomena under review.

From the diminution of the eccentricity of the earth's orbit round the sun, by which the ellipse is in a state of approach to a circle, the annual average of solar radiation is on the decrease; and therefore, as a general cause, and one affecting the mean temperature of the whole globe, and the effect of which is both inevitable and susceptible of exact estimation, it is deserving consideration. Sir John Herschel states, "that an amount of variation in the eccentricity of the orbit, which we need not hesitate to admit, at least provisionally, as a possible one, may be productive of considerable diversity of climate, and may operate during great periods of time, either to mitigate or to exaggerate the difference of winter and summer temperatures, so as to produce alternately in the same latitude of either hemisphere a perpetual spring, or the extreme vicissitudes of a burning summer and a rigorous winter."*

In assuming a temperature in northern regions sufficient to support a tropical vegetation, it must, too, be borne in mind, that light is as indispensable as heat for the luxuriant growth of arborescent ferns, palms, cycadeæ, &c.; and, by analogy, for the gigantic club-mosses and ferns of the carboniferous period. The absence of light for weeks, or months, would probably be fatal to most tropical forms of vegetation. It is therefore as necessary to account for the presence of light as for a high temperature in the northern regions, where the fossil plants indicate the former genial influence of a hot climate, and sunny skies, during the carboniferous epoch.

To account for the existence of regions capable of supporting such a flora as that of the coal-measure, in northern latitudes, a theory,

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* On the Astronomical Causes which may influence Geological Phenomena. Geol. Trans. vol. iii. p. 293.

which it must be admitted is highly ingenious, has been proposed by an American philosopher.* This author, from a comprehensive view of the phenomena which modern geological researches have brought to light, contends that the following general principles may be established:—

"1st. That, notwithstanding the displacements the strata have undergone from subterranean movements, and the destructive effects of deluges and alluvial action, during the lapse of innumerable ages, there remains unquestionable evidence of a great uniform zone of tropical climate, which favoured the existence of vegetable and animal productions of the land and ocean, and formerly surrounded the globe, in a different course from that of the present tropics: and that this is manifest in the organic remains and oceanic deposits, wherever this region is now elevated above the waters.

2dly. That this tropical or torrid zone passed through nearly all the present climates.

3dly. That a uniformity of production has been found upon it in numerous places. And,

Lastly, That the changes on the earth's surface, which have produced the successive strata and organic remains, as far as these are regular, are attributable to the progress of the perihelion point around the ecliptic: and that by the precession of the equinoxes, and the progress of the perihelion rotation of the earth's orbit, the tropical zone, by very slow degrees, has changed, and is still changing its position."

Whether either or both of the above-named causes may be regarded as applicable or adequate to have produced any of the contemplated effects, I must leave to the astronomers to determine: but there is another cause, which was first suggested by Mr. Lyell, that possesses all the essential requisites of a *vera causa;* and that is, the varying influence of the distribution of land and sea over the surface of the earth; and upon which, therefore, I would offer a few comments. A change of such distribution in the lapse of ages, by the degradation of the old continents, and the

* An Essay on Organic Remains as connected with an ancient Tropical Region of the Earth. By Thomas Gilpin, Member of the American Philosophical Society: Philadelphia, 1843.

elevation of new ones, is a demonstrated fact: and the influence of such a change on the climates of particular regions, if not of the whole globe, is a perfectly fair conclusion, from what we know of continental, insular, and oceanic climates by actual observation. "Here, then," observes Sir John Herschel, "we have, at least, a cause on which a philosopher may consent to reason; though whether the changes actually going on are such as to warrant the whole extent of the conclusion, or are even taking place in the right direction, may be considered as undecided, till the matter has been more thoroughly examined."*

50. RETROSPECT; BOTANICAL EPOCHS.—I will conclude this discourse with a review of the prevailing botanical characters during the principal geological epochs.

Count Sternberg, M. Adolphe Brongniart, Dr. Lindley, and other eminent botanists, have adduced some interesting generalizations from the fossil floras of the various formations: and although conclusions of this kind must be regarded in the nature of shifting hypotheses, and will require to be modified by new discoveries—for all the fossil species at present known amount to but two thousand†—

* Discourse on the Study of Natural Philosophy; p. 146.

† M. Göppert computes the number of fossil plants known, to amount to nearly 2,000. Their mineral distribution in the strata is stated to be as follows:—[1]

In the palæozoic strata, below the coal, principally in the Devonian, for the Silurian only contain a few fucoids	52
Carboniferous	819
Permian	58
Triassic	86
Oolitic	234
Wealden	30
Cretaceous	62
Tertiary	454

[1] Brit. Assoc. Reports, for 1845.

yet the characters of the floras of certain formations differ in so striking a manner from those of others, that it is very improbable the essential features will be destroyed.

The flora of the ancient world constitutes three eras. The first period comprehends the earliest strata in which traces of vegetation appear, and includes the carboniferous. The plants of this epoch consist of fuci,* and other cellulosæ, ferns of various kinds in great abundance, coniferous trees related to species of warm climates, of palms and other monocotyledonous tribes; gigantic lycopodia, and trees (Sigillariæ) in great abundance, whose precise relations to known forms is not satisfactorily determined. In this flora the tree-ferns predominate, constituting nearly two thirds of the whole known species, and the general type of the vegetation is analogous to that of islands and archipelagos of intertropical climates.

The second epoch extends from the Triassic or New Red to the Chalk inclusive, and is characterized by the appearance of many species of the Cycadeæ or Zamiæ, and of coniferæ, while the proportion of ferns is much less than in the preceding period, and the lycopodiaceous tribes, calamites, &c. of the carboniferous strata, are absent. A flora of this nature corresponds with that of the coasts and maritime districts of New Holland and the Cape of Good Hope.

The third epoch is that of the tertiary, in which the dicotyledonous tribes appear in great abundance; the cycadeæ are very rare, the ferns in diminished numbers, and the coniferæ are more numerous. Palms, and other intertropical forms, are found associated with the existing European forest-trees, as the elm, ash, willow, poplar, &c., presenting, in short, the general features of our continental floras.

* Fossil fuci abound in the Silurian rocks of the Alleghany Mountains; sometimes forming entire layers, one hundred of which occur in a thickness of twenty feet.—*Dr. Harlan's Medical and Physical Researches*, p. 399.

In the newest strata are imbedded the remains of trees and plants of species still living in the countries where these deposits occur. The fossil foxes and turtles of Œningen (p. 263) lie buried amidst the foliage of poplars, willows, maples, linden-trees, and elms;* and the brown coal of the Rhine is composed of similar trees. In the beds in actual progress, the most delicate vegetable remains are preserved; thus, in the lacustrine marls of Scotland, the leaves and seed-vessels of the Charæ are found in a state of fossilization, scarcely distinguishable from the gyrogonites of the tertiary strata of the Paris basin.

From this review of the botanical epochs which the present state of geological knowledge enables us to establish, we perceive that, from the most ancient formation in which traces of vegetation remain, the sea has supported the usual forms of marine plants; and that on the land, ferns and other cryptogamia, palms, and coniferæ, have existed through periods of indefinite duration to the present time; the most striking and important difference in the ancient and modern floras being the numerical preponderance of the cryptogamia in the former, and of the dicotyledonous tribes in the latter; and the more extensive geographical range of the same species of plants during the carboniferous era. The theory of the progressive development of creation receives no support from the state of vegetation in the early geological epochs; fungi, lichens, hepaticæ, and mosses, do not occur in the coal; but coniferæ, and the most perfectly organized of the cryptogamic class.

The absence of all vegetable forms, except a few species of fucoids, in the most ancient fossiliferous rocks, must not, however, be regarded as a proof that the floras of those remote epochs were thus sterile; the only legitimate inference, in the present state of our knowledge, is, that the circumstances

* See an interesting account of the fossil plants of Œningen, by Professor Braun, of Carlsruhe; Dr. Buckland's Essay, p. 510.

under which those strata were accumulated were unfavourable to the envelopment and preservation of terrestrial plants. We have seen that the grand fundamental distinctions of the vegetable kingdom existed in the early secondary ages, a fact in accordance with what we observed in the animal kingdom: and thus the same unity of purpose and design is manifest in all the varied forms of organization that lived on our planet, through the vast periods of time which geological investigations have enabled us to scan.

LECTURE VIII.

PART I.—THE DEVONIAN, SILURIAN, AND CUMBRIAN FORMATIONS.

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1. INTRODUCTORY. 2. The Devonian System. 3. Subdivisions of the Devonian System. 4. Devonian Strata of Devonshire and Cornwall. 5. Devonian Strata of Scotland. 6. Devonian System of the Continent and America. 7. Organic Remains of the Devonian System. 8. Crustaceans of the Devonian. 9. Fishes of the Devonian. 10. The Silurian System. 11. Subdivisions of the Silurian System. 12. Silurian System of England. 13. Silurian Strata of Staffordshire. 14. The Clent Hills. 15. The Wrekin. 16. The Malvern Hills. 17. Silurian Strata of Europe and America. 18. Fossils of the Silurian System. 19. Silurian Zoophytes and Mollusca. 20. Silurian Gasteropoda and Cephalopoda. 21. Silurian Annelides and Crustaceans. 22. Visual Organs of the Trilobites. 23. Fishes of the Silurian System. 24. The Cumbrian or Schistose System. 25. Structure of Slate Rocks. 26. Slate Rocks of Shropshire and Cumberland. 27. Review of the Silurian and Cumbrian Systems.

1. INTRODUCTORY.—In the previous Lecture the Floras of the palæozoic ages constituted the principal subject of investigation. We examined the primeval forests of coniferæ, and the groves of palms and arborescent ferns, which clothed the surface of the soil in that remote period of the earth's physical history. The insects which fluttered among the tropical vegetation of the islands and continents of those ancient epochs, and the fishes and crustaceans which inhabited the seas and rivers, were brought in review before us, and we contemplated their extraordinary forms and organization, as preserved by those natural processes,

> "Which turned the ocean-bed to rock,
> And changed its myriad living swarms
> To the marble's veined forms."
>
> MRS. HOWITT.

We now advance another stage in our eventful progress; and again we have to investigate deposits that have been accumulating for innumerable ages in the profound depths of seas fed, by rivers and streams charged with the detritus of the countries over which they flowed, and imbedding the remains of the plants and animals that existed at the period of their formation. Again we shall find new forms of existence presented to our notice, differing from, but bearing an analogy to the inhabitants of the waters which deposited the marine strata of the most ancient beds previously examined, yet altogether dissimilar from those of modern eras. In vain may we seek for the remains of the mammalia of the Tertiary periods,—of the mollusca, fishes, and reptiles of the Chalk—of the colossal oviparous quadrupeds of the country of the Iguanodon—of the dragon-forms of the Oolite—of the fish-like lizards of the Lias—or of the tropical forests of the Carboniferous system—all have disappeared; and as the traveller who ascends to the regions of eternal snow, gradually loses sight of the abodes of man, and of the groves and forests, till he arrives at sterile plains, where a few stunted shrubs alone meet his eye; and as he advances, even these are lost, and mosses and lichens remain the only vestiges of organic life; and these too at length pass away, and he enters the confines of the inorganic kingdom of nature:—in like manner the geologist who penetrates the secret recesses of the globe, perceives at every step of his progress the existing types of animals and vegetables gradually disappear, while the relics of other creations teem around him; these in their turn vanish from his sight—other new and strange modifications of organic structure supply their place—these also fade away—traces of animal and vegetable life become less and less manifest, till they altogether disappear—and he descends to the primary rocks, where all evidence of organization is lost, and the granite, like a pall thrown over the relics of a former world, conceals for ever the earliest scenes of the earth's physical drama.

2. The Devonian System.—I purpose in this division of the present Lecture to consider the characters and relations of the three remaining systems of fossiliferous deposits, namely, the Devonian, Silurian, and Cumbrian: all the rocks of more ancient date, so far as our present knowledge extends, being destitute of any traces of organization, whether of the animal or of the vegetable kingdoms.

The Devonian system, formerly called the *Old Red Sandstone* (*ante*, p. 204), lies immediately beneath the Carboniferous limestone, and is largely developed in Devonshire, Herefordshire, Monmouthshire, &c.: and in the south-east border of the Grampians, and over the whole of the northern part of Scotland. It consists of many alternations of conglomerates, shales, and sandstones, in various states of induration. The sandstone is often of a schistose character, and this variety is largely employed for roofing, under the name of *tilestone*. The conglomerates are formed of quartz pebbles, waterworn fragments of slate and other rocks, cemented together either by an argillaceous or a siliceous paste, coloured, more or less, of a deep red, by peroxide of iron. These strata have evidently resulted from the degradation of ancient slate rocks; for they are entirely made up of pebbles, sand, and mud, accumulated in depressions of the bed of the sea. The mountains of Scotland are bordered by immense deposits of a like character; and those of North and South Wales by red pebbly sandstone. Some eminent geologists are of opinion that prior to the formation of the Devonian deposits, the Cumbrian slaty group of sands, flag-stones, &c., with porphyritic conglomerates, had been long consolidated; and that they were subsequently elevated by subterranean movements, and thrown on edge, and formed an irregular island; and at the same time parts of the Grampians, Lammermuirs, and the slaty districts of

Ireland and Wales, and the Ocrynian chain of Cornwall, were above the waters.

3. SUBDIVISIONS OF THE DEVONIAN SYSTEM.—The uppermost beds of this system, for the most part, dip conformably beneath the mountain limestone, or other members of the Carboniferous, and the lowermost pass into strata that belong to the upper series of the Silurian. For the convenience of study, the deposits comprised in this formation are subdivided into three groups :—

I. QUARTZOSE CONGLOMERATES and SANDSTONES and MARLS. The sandstones are often either of a deep chocolate red, or greenish colour. The marls partake of the same tints, but are frequently mottled with blotches of red and green. Fishes of the genus *Holoptychius*.

II. CORNSTONE and MARLS. Irregular bands of concretionary limestone, provincially termed *Cornstone;* with intercalations of marl; the same colours prevailing as in the upper group. Abound in remains of *Cephalaspis* and other fishes.

III. TILESTONES. Finely laminated quartzose or micaceous sandstones, termed *tilestones,* from the facility with which they are separated into thin slabs or tiles. Contain shells, and fishes of the genus *Dipterus,* &c.

The total thickness of this system in Herefordshire and South Wales, is estimated by Sir R. Murchison at 10,000 feet. Of its extent, in this part of Britain, the following remarks of the same eminent geologist will give a clear idea. "Occupying the largest portion of Herefordshire, and the adjacent districts of Worcestershire and Shropshire, it spreads over wide tracts of Monmouthshire, surrounding the coal-field of the Forest of Dean; and forming a girdle round the great South Welsh coal basin, it constitutes in Brecknockshire the loftiest mountains of South Britain. The enormous thickness of the red stratified deposits included between the coal-measures and the Silurian rocks, will at once be comprehended by any observer who places himself on the eastern slopes of the latter on the Welsh borders of Herefordshire, near Kingston for example; whence casting his eye to the south and south-east, the circle of vision, although extending over all the hills between the Wye and the Usk, and terminating only in the lofty mountains called the Brecon and Caermarthen Fans, 2,500 feet above the sea-level, embraces nothing but Devonian sandstone. This view does not include a wide superficies, occupied merely by undulating masses of the same strata, but a territory in which successive members of the system rise from beneath each other in distinct mountainous escarpments. The same succession, though on a much smaller scale, is displayed in Shropshire, between the coal-field of the Clee Hills and the older rocks of Ludlow; whilst in the central districts of Herefordshire the strata lie in a great basin, the lower edges of which are turned up against the Silurian rocks, both on their eastern and western flanks."*

The red conglomerates of this system are well displayed on the right bank of the Wye from Monmouth to Tintern Abbey (*Medals*, p. 930): and beds of the Devonian sandstone and conglomerate form the base of the mountain limestone at the embouchure of the Avon, and the central nucleus or axis of the Mendip Hills (*ante*, p. 522).

4. Devonian strata of Devonshire and Cornwall. —In the south of Devonshire, in many places dipping towards the anthracite or carboniferous shales of the northern part of the district (*ante*, p. 683), there is an extensive series of strata, composed of green chlorite slates, alternating with quartzose shales and sandstones, with blue and grey limestones, which pass into, or are associated with, red sandstones and conglomerates. Many of these beds abound in organic remains. The slates of Devonshire were formerly regarded as belonging to the earliest or most ancient fossiliferous

* Silurian System, p. 170.

strata—the *Transition rocks*, as they were termed; till the researches of Professor Sedgwick and Sir R. Murchison ascertained their true position and relations, and the unity of type which prevails in the organic remains of the entire system, in places very distant from each other, and under very dissimilar conditions of mineral character. The beautiful coralline marbles of Babbicombe, Torquay, &c. (*ante*, p. 643) belong to this formation.

In Cornwall, which principally consists of Devonian strata, with slates, and intrusive igneous rocks, Silurian deposits have lately been detected. The *killas*, or metamorphic schists, of the southern headlands of the coast, contain many fossils typical of the Lower Silurian; and Sir R. Murchison states that the geological structure of Cornwall may now be regarded as presenting the following series:—

1. The lowermost: a band of Silurian deposits.
2. A zone of an intermediate character, forming a transition between the Silurian and Devonian.
3. A Devonian system characterized by lower and upper limestones.
4. An extension of the culmiferous (*carboniferous*) strata of Devonshire.*

The *killas* are argillaceous strata that have been indurated by metamorphic action, like those of Scandinavia and the Ural mountains; and as in those countries the granites and porphyries of Cornwall, traverse the palæozoic deposits.

Sir R. Murchison further remarks, that the stanniferous (*tin*) gravels of Cornwall bear the same relation to the granite and killas, as the auriferous deposits of the Urals to the erupted and schistose rocks of that chain.

On the opposite side of the Channel, in Brittany and Normandy, the same mineral type prevails; namely, Caradoc sandstone and other Silurian, with Devonian and Carboniferous strata.

* Jameson's Edinburgh Journal for July, 1847.

5. Devonian System of Scotland.—The deposits of this system occupy an important place in the geology of Scotland, and have of late years attracted considerable attention, from the interesting fossils they have yielded, and the admirable illustrations of the most important phenomena, given by Mr. Hugh Miller, in his delightful work.* According to this charming writer, the whole of the northern part of Scotland, from the Pentland Frith to the mouth of the river Spey, consists of Devonian deposits resting on a central nucleus of primary rocks, viz., granite, gneiss, and micaceous schists. Similar strata are also found in insulated patches in various places of the interior of the country. "They cap some of the higher summits in Sutherlandshire; form an oasis of sandstone among the primary districts of Strathspey; rise on the northern shores of Lochness in an immense mass of conglomerate, based on a small-grained red granite, to a height of three thousand feet above the sea-level; and on the north-western coast of Ross-shire, form three immense insulated hills (*Suil Veinn, Coul Beg, and Coul More*†), of as great

* The Old Red-sandstone; or, New Walks in an Old Field. By Hugh Miller. Edinburgh, 1841: 1 vol. 12mo, with plates.

† These insular mountains of Old Red, are cited by Dr. Macculloch (Western Isles, vol. ii. p. 90), and Mr. Lyell (Elements of Geology, vol. i.), as instructive examples of the vast amount of denudation which has taken place in many countries. Mr. Lyell observes: "The fundamental rock of this part of Scotland is gneiss in disturbed strata, on which beds of nearly horizontal red-sandstone rest unconformably. The latter are often very thin, forming mere flags, with their surface distinctly ripple-marked. They end abruptly on the declivities of many insulated mountains, which rise up at once to the height of about two thousand feet above the gneiss of the surrounding plain or table land, and to an average elevation of about three thousand feet above the sea, which all their summits generally attain. It is impossible to compare these scattered and detached portions without imagining that the whole country has once been covered with a great depth of sandstone, and that masses from one thousand to more than

an altitude, that rest unconformably on a base of gneiss."* South of the Grampians, Devonian strata underlie the carboniferous system of Fifeshire; and a zone of these deposits skirts the southern flank of those mountains, from Stonehaven to the Frith of Clyde; and constitutes, with intrusive trap rocks, the Sidlaw Hills and the Valley of Strathmore. In a section of the country from the foot of the Grampians in Forfarshire, to the sea at Arbroath, a distance of about twenty miles, where the entire mass of strata is several thousand feet thick, the triple division of the system is very obvious; namely, 1st, and uppermost, red and mottled marls, cornstone, and sandstone. 2. Conglomerates, often of vast thickness. 3. Tiles and paving stones, highly micaceous. The lowermost beds contain remains of fucoid plants in abundance.† According to the observations of Mr. Miller, each group is characterized by the prevalence of a peculiar type of fishes (see *ante*, p. 752).

From the extension of the Devonian strata along the northern shores of Scotland, numerous bays, friths, and estuaries, have been produced by the long-continued action of the sea, as is strikingly exemplified between Sutherlandshire and Inverness.‡ "In a line of coast but little more than forty miles in extent, there are four arms of the sea, namely, the Friths of Cromarty, Beauly, and Dornoch, and the Bay of Munlochy. The Frith of Tay, and the Basin of Montrose, are also semi-marine valleys of the Old Red-sand-

three thousand feet in thickness have been removed."—*Elements of Geology*, 2d edit. vol. i. p. 141.

* Ibid. p. 23. † Ibid. vol. ii. p. 148.

‡ "The county of Sutherland stretches across Scotland from the German to the Atlantic Ocean, and presents throughout its whole extent—except where a narrow strip of the Oolite formation runs along its eastern coast—and an interrupted belt of Old Red-sandstone tips its capes and promontories on the west—a broken and tumultuous sea of primary hills."—*Mr. Miller*, p. 30.

stone. Two of the finest harbours in Britain, or the world, belong to this formation—Milford Haven, in South Wales, and the Bay of Cromarty;"* the latter, Mr. Miller's researches and writings have made classic ground to the geologist.

The predominating colour of the sandstones and conglomerates has probably been derived from the red granitic gneiss which forms chains of precipitous ridges in the north of Scotland. This rock contains hæmatitic iron-ore, diffused as a component of the stone throughout its entire mass; and this metal also occurs in insulated blocks of great richness, and in thin filiform veins.†

6. Devonian of the Continent and America. — In the Rhenish provinces and adjacent districts of Germany, Devonian strata underlie the carboniferous system, and may be traced around, and dipping under the coal-field of Westphalia.‡

In Russia, according to the researches of Sir R. I. Murchison, the Devonian system extends over an area of 150,000 square miles, a region more spacious than the British Isles; and yet, throughout this vast superficies, the subdivisions of the system are as distinctly characterized by their respective fossils as in the disturbed districts of our own little island.||

In North America, the Devonian deposits appear in a very prominent and characteristic form; surrounding each of the great coal-fields of the United States. The Silurian rocks, which are largely developed in those countries, are more or less overlaid by shales, sandstones, and flagstones of this system; and these are surmounted by red sandstone, containing remains of the fishes and shells peculiar

* Miller's Old Red-sandstone, p. 205.
† Ibid. p. 248.
‡ Prof. Sedgwick and Sir R. I. Murchison.
|| Sir R. I. Murchison's Geology of Russia.

to the equivalent deposits of England. These Devonian beds are covered by carboniferous strata, distinguished, as in Europe, by marine shells of the genera, *Leptæna*, *Bellerophon*, *Euomphalus*, *Goniatites*, &c., associated with land plants.

7. ORGANIC REMAINS OF THE DEVONIAN.—The deposits comprised under the name of the Old Red were formerly regarded as very sterile in organic remains, and classed among the so-called Transition rocks, in which, it was supposed, traces of animal life first appeared. Modern researches have, however, shown that though many of the strata are locally unproductive in fossils, yet others abound in the remains of corals, shells, crustaceans, and fishes; the marine fauna of this epoch being extremely rich, and containing certain peculiar types, but, as a whole, forming a connecting link between the zoology of the Carboniferous system which followed, and the Silurian which preceded it.

Ichthyolites are abundant in the sandstones of Caithness, Cromarty, and other Devonian localities in Scotland, but shells are rare; while in Devonshire, testaceæ and crustaceans are numerous.

Plants. Of the vegetable kingdom, the only traces found in the Devonian system—with the exception of occasional intercalations of thin layers of coal, and carbonaceous strata—are those of fucoid plants, impressions of which appear on the surfaces of many of the laminated sandstones. In the lower Devonian strata in Forfarshire these supposed fucoid remains are very abundant, and are often accompanied with groups of small flattened hexagonal carbonaceous bodies, which occupy slight depressions in the stone or shale; these fossils, Mr. Lyell believes to be the eggs of gasteropodous mollusca, for they closely resemble those of the recent *Natica*.*

* Elements of Geology, p. 151.

Zoophytes. The Corals and Crinoidea are numerous, and most of the genera, and many of the species, are equally abundant in the Carboniferous system. The *Favosites*,* and *Cyathophylla*,† are common both in the mountain limestone and in the Devonian marbles. The Crinoideans comprise several genera, and some peculiar species of *Cyathocrinus* (*ante*, p. 655), and *Pentremites* (p. 650).

Mollusca. The shells in some districts are very numerous, consisting of many genera of gasteropoda; as, *Buccinum*, *Turbo*, *Pleurotomaria*, &c.; and conchifera, as *Cucullæa*, *Avicula*, *Pecten*, &c.

But the most remarkable feature in the conchology of this epoch is the abundance of the ancient types of brachiopoda. In the British Devonian strata alone have been determined of *Atrypa*, 20 species; *Leptæna*, 7; *Orthis*, 16; *Spirifer*, 34; *Terebratula*, 30.

Cephalopoda. Of the higher order of molluscous animals, species of seven or eight genera are met with. The most common belong to *Bellerophon*, *Orthoceras*, *Cyrtoceras*, *Goniatites*, and *Clymenia*; the latter differ from the Goniatites in being flattened, and having an internal siphuncle, and angular septa.‡ The Orthoceratites in the limestones of Devonshire often attain a large size. The shell is commonly changed into white calcareous spar, which in sections, forms a beautiful contrast with the red hue of the surrounding rock.§

8. CRUSTACEANS OF THE DEVONIAN SYSTEM.—In this formation the palæozoic types of Crustaceans, the Trilobites, begin to appear in considerable numbers, and prepare us for the myriads that are imbedded in the Silurian rocks. The

* Medals of Creation, p. 295. † Ibid. p. 298.

‡ See Mr. Lyell's Elements of Geology, p. 156, fig. 342.

§ Polished slices of marble marked with sections of Orthoceratites are sold by the lapidaries of Torquay and Teignmouth.

Calymene (*Lign.* 178) is a common form; and a very peculiar modification of this family, termed *Brontes*,* has hitherto been found only in the Devonian deposits.

Eurypterus.† A large species of this extinct genus of crustaceans occurs in the Devonian sandstone of Forfarshire; and fragments of the case or shell have long been known to collectors as "*petrified Seraphims*," the name applied to these fossils by the quarrymen, from their fancied resemblance to the conventional figures of cherubs. The first specimens which threw light on the nature of the original were discovered by Mr. Miller at Balruddery. The carapace of this animal forms a lozenge-shaped shield, and the appendage of the post-abdomen is a continuous flap. The claws resemble those of the common lobster. The crustaceous covering, or shell, is ornamented externally with circular and elliptical markings, which give it an imbricated or scaly appearance: and it was the imprints of this surface that produced the enigmatical fossils to which the workmen ascribed a celestial origin! Some specimens indicate a total length of four feet.‡

9. Fishes of the Devonian System.—M. Agassiz has determined no less than one hundred species of fossil fishes from the Devonian formation, in which, but twenty years since, a few doubtful scales discovered in Forfarshire by Dr. Fleming, were the only known vestiges of this class of vertebrated animals. In the British series, there are upwards of sixty species, belonging to twenty-six genera.§ Of these, the most characteristic are the *Cephalaspis*, *Pterichthys*, and *Coccosteus*, which form a group of extinct genera, that has no representatives in the Silurian

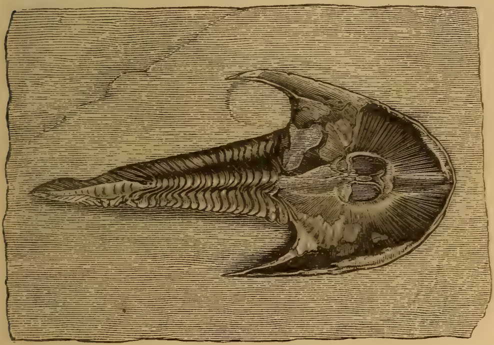
* Medals of Creation, p. 559. † Ibid. p. 541.

‡ See New Walks in an Old Field, p. 147. There are specimens of this crustacean in the British Museum from the quarries of Carmylie.

§ See Mr. Tennant's Stratigraphical List of British Fossils, p. 119.

formation below, nor in the Carboniferous rocks above; nor, except by distant and faint analogies with existing fishes, can these remarkable organisms be brought within the pale of zoological arrangement. These ichthyolites agree in one general character, that of having relatively enormous osseous or horny plates, or escutcheons. Their general appearance will be understood by reference to *Lign.* 171, 172, which represent a remarkable specimen of the first-named genus, discovered by Mr. Lyell.

Cephalaspis. In the Old Red-sandstone underlying the

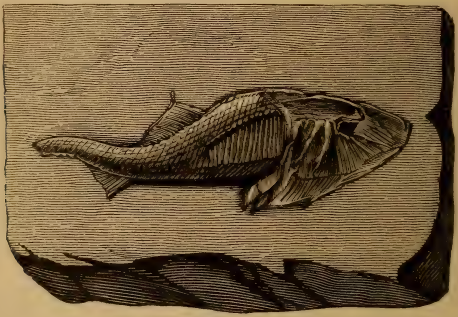


LIGN. 171.—CEPHALASPIS LYELLII.

From Glammis, in Forfarshire; a fish peculiar to the Devonian system.

(*One-fourth the natural size.*)

carboniferous strata of Scotland, scales and other remains of fishes were discovered many years since by Dr. Fleming. These relics belong to the extraordinary genus of fishes, named *Cephalaspis (Buckler-head)* by M. Agassiz, from the head being covered by a buckler or shield, and the plates united into one osseous case. The scales form elevated bands, and the rays of the fins are covered by the membrane which elsewhere surrounds them. From the large size of the plate which covers the head, its lamellar structure, and crescent-like form, terminating in two horns or points, detached specimens were formerly supposed to belong to trilobites or some other crustaceans. The whole body is covered with scales, and those of the head are highly ornamented with radiated markings. The tail is a long pedicle supporting a fin.* Numerous remains of these fishes have been found in the



LIGN. 172.—CEPHALASPIS LYELLII.
Lateral view, showing the produced dorsal lobe of the tail.

Devonian strata of England, Scotland, and even Russia. Mr. Miller states they are principally restricted to the middle group, the cornstone and marls (*ante*, p. 752).

Pterichthys.† The fishes of this genus are distinguished by two wing-like lateral appendages, which, like the spines of the common Bull-head (*Cottus gobio*), were weapons of defence. The head and anterior part of the body are covered with large angular tuberculated scutcheons. There are two eyes, which are placed in front of the lateral spines. Five or six species occur in the British strata; all very

* Medals of Creation, p. 645.

† Winged-fish. Medals of Creation, p. 648.

small, the longest not exceeding eight or ten inches in length. But in the Devonian system of Russia, gigantic species are met with. I have seen in Sir R. I. Murchison's collection specimens and models in which the lateral spines are one foot in length.

*Coccosteus.** In form, and in the arrangement of the horny scutcheons, the fishes of this genus have a close resemblance to the Pterichthys. The plates are tuberculated; the tail is very long, covered with scales, and supports a fin. There are four or five species, varying in length from a few inches to two feet. Their remains are the most abundant of the ichthyolites of the Old Red system. Patches of detached scales, and insulated osseous plates, are very frequent in the sandy cornstones and subcrystalline limestones. They are usually of a brilliant blue or purple colour, which strongly contrasting with the dull red tint of the surrounding rock, renders them easy to be detected. This colour is supposed to be due to the presence of phosphate of iron, which has communicated a similar tint to the ichthyolites of the Caithness schists.† In none of these fishes have any traces of vertebræ been discovered; it is therefore probable that the spinal column was cartilaginous, as in the Sturgeon.

Holoptychius. My limits will only admit of a rapid notice of a few other Devonian ichthyolites. Among these, several species of the large sauroid fishes, named *Holoptychius*, from the peculiar character of the scales, are most strikingly conspicuous. This genus we have already noticed in the account of the carboniferous ichthyolites (*ante*, p. 741).‡

* *Berry-bone fish*: from the plates being studded over with small tubercles. Medals of Creation, p. 648.

† Silurian System, p. 588.

‡ A splendid specimen of *H. nobilissimus*, twenty-eight inches long, is figured in Silurian System, pl. 2, and is now in the British Museum.

Dendrodus. This fish is allied to the Holoptychius, but the structure of the teeth, scales, and occipital plates, are peculiar. The teeth are of a conical form, slightly curved, solid throughout, and finely striated longitudinally; and the medullary canals and calcigerous tubes are so disposed as to produce a dendritical, or arborescent appearance, in transverse sections; a character which is expressed by the name, Dendrodus.*

Dipterus, and *Diplopterus*, are two nearly related genera of ganoid fishes, so named from their possessing two dorsal fins, which are placed opposite the anal and ventral fins. These fishes, together with the *Osteolepis*, another common Devonian genus, have bony scales plated with enamel, and finely punctated; jaws, consisting of enamel without and bone within, and beset with sharp-pointed teeth; "closely jointed plates burnished like ancient helmets, cover their heads, and seem to have formed a kind of outer table to skulls externally of bone and internally of cartilage: these gill-covers consist each of a single piece like that of the Sturgeon; their tails were formed chiefly on the lower side of their bodies; and the rays of their fins, enamelled like their plates and their scales, stand up over the connecting membrane, like the steel or brass in that peculiar armour of the middle ages, whose multitudinous pieces of metal were fastened together on a ground-work of cloth, or of leather. All their scales, plates, and rays, present a similar style of ornament."†

Glyptolepis, Cheirolepis, and *Cheiracanthus*, are other characteristic fishes of this system of deposits.‡ Of

* Medals of Creation; see p. 653. Pl. VI. fig. 8, represents a portion of a tooth highly magnified.

† Miller's New Walks in an Old Field, p. 80.

‡ Consult Mr. Miller's work above quoted; and M. Agassiz's beautiful Monograph on the fishes of the Old Red-sandstone; published by Mr. Baillière; and Sir R. Murchison's Silurian System.

the placoid fishes, species of the genera Onchus and Ctenacanthus have been discovered; but this order is but feebly represented in the Devonian epoch, while the ganoid is largely developed; the *Cephalaspides* and the *Dypterians* appear exclusively in these strata.*

10. The Silurian System.—By a reference to the synoptical arrangement of the formations (*ante*, p. 204—206), it will be seen, that the interval between the Devonian system, and the uppermost of the hypogene rocks, the *Mica-schist*, is occupied by an immense thickness of slate rocks, limestones, sandstones, and argillaceous strata. These deposits were formerly grouped together under the name of *Transition rocks*; a designation applied by the celebrated Werner, upon the supposition that they were formed when the world was in a state of transition from a chaotic to a habitable condition: they were also termed *Grauwacké*,† from the hardened conglomeritic character of many of the strata; but the whole series is now divided into two natural groups. The uppermost is designated the Silurian System,‡ by Sir R. Murchison, whose indefatigable researches have determined the true position, relation, and character of these deposits: and the lowermost, consisting principally of slate rocks, has been named the Cumbrian System,§ by Professor Sedgwick, whose successful labours in this difficult field of geological investigation, have rendered clear and intelligible pheno-

* See M. Agassiz's Genealogical Table in Recherches sur les Poissons Fossiles, tom. i. p. 170.

† From the German *grau*, grey, and *wacké*, a name employed by the German miners to denote hardened conglomerates.

‡ *Silurian*—a term derived from *Silures*, the ancient Britons who inhabited those parts of our Island where these strata are most distinctly developed.

§ *Cumbrian*, from the Lake district of Cumberland, which is principally composed of slate rocks. In the Map, p. 464, the Silurian and Cumbrian systems are denoted by the same number (8) and colour.

mena which were previously involved in doubt and obscurity.

The Silurian system is largely developed in the border counties of England and Wales, and spreads over a considerable area of South Wales, forming a link which connects the Devonian series with the ancient slate rocks of that country. The strata are named and characterized by Sir R. I. Murchison according to the following table:—

THE SILURIAN SYSTEM.

(*Commencing with the uppermost*).

Upper Silurian: thickness about 4,000 feet.	*Ludlow* rocks*—slightly micaceous grey-coloured sandstone. Blue and grey argillaceous limestone. Dark-coloured shales and flag-stones, with concretions of earthy limestone, containing orthocerata, spirifers, and trilobites. *Fishes*.
	*Wenlock,** or *Dudley limestone* — sub-crystalline blue and grey limestone—abounding in trilobites, crinoidea, polyparia, spirifers, orthocerata, &c.
	Wenlock shale—dark-grey argillaceous shale, with nodules of sandstone.
Lower Silurian: thickness about 3,500 feet.	*Caradoc† sandstone*—shelly limestones, and finely laminated, slightly micaceous greenish sandstones. Corals, mollusca, trilobites. *Fishes*.
	Llandeilo‡ flags and sandstones. Freestone, conglomeritic grits, sandstones, and limestones. Dark-coloured flags. Beds of schist with abundance of trilobites and mollusca.

Total thickness, nearly 8,000 feet. §

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* Towns in Shropshire, situated on the respective strata thus designated.

† *Caradoc*, or *Caractacus*, from the Caradoc hills of Shropshire, so named from the celebrated British chief.

‡ *Llandeilo*; so named from a town in Caermarthenshire.

§ The SILURIAN SYSTEM, founded on geological researches in the border counties of England and Wales, with descriptions of the coal fields and overlying formation; by Roderick Impey Murchison, F.R.S., The whole of these strata are of marine origin, without any interspersions of fresh-water or terrestrial detritus whatever; and the limestones swarm with trilobites, crinoidea, corals, spirifers, leptænæ, and other fossils, with which our late investigations have made us familiar. The subdivisions introduced are locally important; but a general analogy prevails in the organic remains throughout the entire system, and there does not appear to be any essential variation in the forms or conditions of organic life, as deducible from the fossils, from the commencement to the termination of the series; and though each principal division may be distinguished by its peculiar fossils, yet the upper and lower Silurian rocks are bound together by species common to both, and form but one natural system, though for convenience they are classified in two groups.

11. Subdivisions of the Silurian System. — The Upper Silurian comprises the *Ludlow rocks*, so named from their great development around Ludlow, in Shropshire; they are subdivided as follow:—

(*a.*) *Upper Ludlow*, consisting of micaceous and calcareous sandstone, decomposing into soft mud: a few species of shells common in the lower Devonian occur, and some (*Orthis orbicularis*) that have not been observed in

&c. In two parts, royal 4to. with a separate map, and numerous illustrations. London, 1839; p. 768. The publication of this splendid work formed an era in British Geology: it is a noble monument of patient, laborious, and successful scientific research, pursued through a long series of years, regardless of toil, time, or expense. The results of the labours of its highly-gifted author are alike novel and important: rocks, which, under the names of transition and greywacké (terms that served as a veil for our ignorance), were previously considered without the pale of scientific arrangement, were for the first time reduced to a regular system, and their zoological characters as well defined as those which mark the newer secondary formations. The addition made to the geological fauna by the author, amounts to nearly 400 species. This is truly a national work: the description of the British coal-fields is as important in an economical, as in a scientific point of view.

other deposits. The lowermost strata, to a thickness of thirty feet, are literally made up of brachiopodous shells (*Terebratula navicula*).

(*b.*) *Aymestry limestone.* Principally argillaceous and subcrystalline limestones; characterized by the prevalence of the remarkable brachiopodous shell, the *Pentamerus*,* a genus only found in the Silurian deposits.

(*c.*) *Lower Ludlow rocks.* A series of shales and concretionary limestones, distinguished by the presence of some peculiar chambered shells (*Lituites, Phragmoceras*), Trilobites (*Homalonotus*), and zoophytes allied to the Sea-pens (*Graptolites*).†

The inferior series of the Upper Silurian consists of the *Wenlock shales and limestones;* but the latter are better known as the *Dudley limestones*, from the interest and variety of the organic remains with which the strata in the vicinity of that town abound.

From the profusion of Trilobites, shells, and corals, displayed in relief on the surface of the slabs of the Dudley limestone, many of the specimens are of surpassing interest; they are, indeed, tablets of stone, inscribed with the typical hieroglyphics of the palæozoic ages.

The Lower Silurian formation is divided into two groups;—

(*a.*) The *Caradoc sandstones*, consisting of shelly limestones and sandstones, which contain trilobites, and cephalopodous and brachiopodous shells, unknown in the upper strata (as *Pentamerus lævis, Orthis grandis*, &c.); and, (*b.*) the *Llandeilo flags*, which are dark-coloured micaceous schists and flagstones, that form the base of the Silurian system. In these lowest deposits some large Trilobites (*Asaphus Buchii*), and certain species of Graptolites occur, and are regarded as characteristic.

12. SILURIAN SYSTEM OF ENGLAND.—Both the litho-

* Medals of Creation, p. 383. † Ibid. p. 290.

logical and zoological characters of this system, and even of its principal subdivisions, are found to prevail not only in England, and over the continent of Europe, but also in North America, where the Silurian rocks are largely developed, and form the principal ranges of the Alleghany mountains.

In Cornwall, Silurian rocks appear in several places, emerging from beneath the predominant strata of the district, the Devonian, and containing characteristic fossils.* But the grand development of this system is in the border counties of England and Wales, including, according to Sir R. Murchison, the whole of the slate rocks of North Wales; the fossils found in the latter entirely corresponding with those of the Lower Silurian deposits. "Even in the Lake districts, with a great expansion of equivalents of the Ludlow and Wenlock rocks, there are no organic remains of higher antiquity than the upper part of the Lower Silurian: and however differing in mineral characters, and containing a few species of fossils hitherto undetermined, all the great inferior masses of that region and of North Wales, are the equivalents of those to which the term Lower Silurian is applied. The Cumbrian system of Professor Sedgwick is, therefore, identified in zoological type with the Lower Silurian deposits."†

13. Silurian strata of Staffordshire.—Among the British Silurian districts, the country around Dudley, Walsall, and other parts of Staffordshire, demand especial notice from the interesting circumstances under which these palæozoic rocks occur; being isolated, as it were, from the great regions of the formation, and thrown up amidst the newer deposits, like islands in the Triassic and Carboniferous systems: and the facility of access to these localities, by the railroads from the metropolis, renders them peculiarly valuable to the geological student.

* Sir R. Murchison; *ante*, p. 754. † Ibid.

At the distance of about 120 miles from London, an insulated mass of Silurian rocks is protruded through the once overlying Triassic and Carboniferous strata at Walsall, and forms a ridge of hills on the eastern borders of the great Staffordshire coal-field; while near Dudley, a few miles to the south-west, another range of Silurian hills, produced by a similar upheaval, appears in the midst of the same carboniferous basin; and near these hills is a mass of volcanic rocks, called Rowley Hill.*

The town of Dudley is situated partly on the coal-field, and partly on the group of Silurian rocks which constitutes a prominent feature in the physical characters of the landscape. These Silurian deposits rise into an elevated chain of hills, which extends four or five miles diagonally across the coal-basin, in a line from Dudley to Wolverhampton; the latter town standing on Triassic strata near the western margin of the coal-field.† The aspect of the surface of the country denotes the nature of the sub-soil, for the Triassic districts are generally covered with verdure; while those of the coal, from the extensive mining operations every where in progress, present for the most part a character of sterility and desolation.

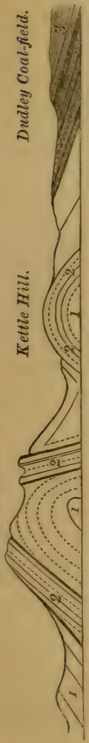
In the Dudley Silurian range, three hills are strikingly conspicuous, namely Sedgley, which is composed of the Upper Ludlow rock and Aymestry limestone; and the Wren's Nest, and the Castle Hill, consisting of Wenlock shale and limestone; these hills, with their connecting valleys, form a verdant tract in the midst of the surrounding coal-measures.

The most remarkable eminence of this group is that called the *Wren's Nest*, which is a steep headland, covered on the top with stunted wood, and presenting the appearance

* See the beautiful geological map that accompanies Sir R. Murchison's work on the Silurian System.

† See *ante*, p. 673, for an account of a colliery near Wolverhampton.

of a truncated dome; its summit is deeply excavated, whence the common ironical name. This hill, as shown in *Lign.* 173, consists of arched strata of Wenlock shale and limestone. The limestone teems with the characteristic fossils of this division of the Silurian system, namely, *Terebratulæ*, *Lingulæ*, *Orthes*, *Atrypæ*, and *Trilobites*, *Crinoidea*, *Corals*, &c. Castle Hill, and Hurst Hill, are similar and parallel upheaved masses.

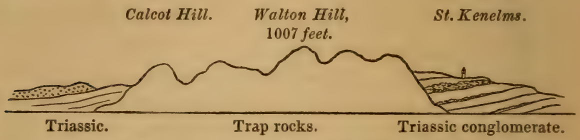


LIGN. 173.—SECTION OF SILURIAN AND CARBONIFEROUS STRATA, NEAR DUDLEY.

The truncated appearance of the summit of Wren's Nest, has evidently originated from the denudation of the upper part of the dome of which it once consisted: the strata having been originally protruded in an arched position, as in Kettle Hill (see the section, *Lign.* 173); and we have in these Silurian limestones and shales, a corresponding structure with that observable in the mountain limestone of Crich Hill in Derbyshire, of which we have already spoken (*ante*, p. 685).

14. THE CLENT HILLS.—In the above section, the upheaved and contorted sedimentary deposits are alone displayed, the deep-seated volcanic mass, by which they were elevated and thrown into their present position, being concealed from view. But in several places in the surrounding district, the intrusive igneous rocks appear above the surface, in sharply-defined ridges; as in the Rowley Hill, near Dudley, and those of the Clent, Romsley, and Lickey; and the more distant ranges of Abberley, and the Malverns, in Worcestershire.

About two miles to the south of the Dudley coal basin, and stretching in a parallel direction with the Silurian range previously described, is another chain of hills, about



LIGN. 174.—SECTION OF THE CLENT HILLS.

(*Sir R. Murchison's Sil. Syst.*)

six miles in length, and varying in height from 800 to 1000 feet, called the Clent Hills.* This elevated district is formed by a protrusion of felspathic trap rocks through the Triassic strata, as shown in *Lign.* 174.† This basaltic eruption must have taken place after the carboniferous strata were deposited, and long antecedent to the Triassic.

The following description by Mr. Hugh Miller is too graphic to be omitted.—

" The New Red-sandstone, out of which the Clent Hills arise, forms a rich, slightly undulating country, reticulated by many a green lane and luxuriant hedge-row; the hills themselves are deeply scooped by hollow dells, furrowed by shaggy ravines, and roughened by confluent eminencies; and on the south-western slopes of one of the finest and most variegated of the range, half on the comparatively level red sandstone, half on the steep-sided billowy trap, lie the grounds of Hagely. Let the Edinburgh reader imagine such a trap hill as that which rises on the north-east between Arthur's Seat and the sea, tripled or quadrupled in its extent of base, hollowed by dells and ravines of considerable depth, covered by a soil capable of sustaining the noblest trees, mottled over with votive urns, temples, and obelisks,

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* Within the precincts of the Clent Hills are Hagely, the seat of Lord Lyttleton, which the muse of Thomson has rendered classic ground; and the equally celebrated Leasowes of Shenstone.

† The trap or volcanic rock of the Clent, Lickey, and Abberley Hills, is chiefly composed of brownish-red compact felspar, occasionally porphyritic, and sometimes passing into a fine concretionary rock.—*Sir R. Murchison; Sil. Syst.* p. 496.

and traversed by many a winding walk, skilfully designed to lay open every beauty of the place, and he will have no very inadequate idea of the *'British Tempe,'* sung by Thomson. We find its loveliness compounded of two simple geological elements,—that abrupt and varied picturesqueness for which the trap rocks are so famous, and which may be seen so strikingly illustrated in the neighbourhood of Edinburgh; and that soft-lined and level beauty—an exquisite component of landscape when it does not stand too much alone—so characteristic, in many localities, of the New Red-sandstone formation. From the hill-top,* the far Welsh Mountains, though lessened in the distance to a mere azure ripple, that but barely roughens the line of the horizon, were as distinctly defined in the clear atmosphere, as the green luxuriant leafage in the foreground which harmonized so exquisitely with their blue. The line extended from far beyond the Shropshire Wrekin, on the right, to far beyond the Worcestershire Malverns, on the left. In the foreground we have the undulating trap; next succeeds an extended plain of the richly-cultivated New Red-sandstone, which, occupying fully two-thirds of the entire landscape, forms the whole of what a painter would term its middle ground. Then rises over this plain, in the distance, a ridgy acclivity, much fretted by inequalities, composed of the Old Red-sandstone formation, coherent enough to have resisted those denuding agencies by which the softer deposits have been worn down; while the distant sea of blue hills, that seems as if toppling over it, has been scooped out of the Upper and Lower Silurian formations, and demonstrates in its commanding altitude and bold wavy outline, the still greater solidity of the materials which compose it." †

15. THE WREKIN.—The Dudley coal-field is remarkable for the beds of volcanic grit intercalated between the upper strata of the coal-measures and the lowermost triassic deposits; and which Sir R. Murchison is of opinion were formed from the detritus of submarine volcanos, which were in activity towards the close of the carboniferous epoch.‡ The solid intrusive trap rocks are of a later date,

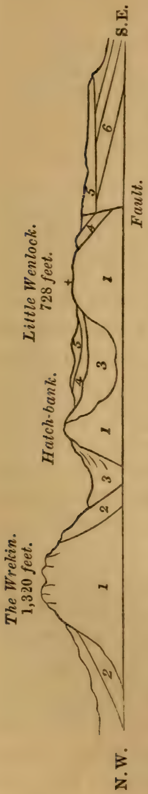
* The eminence so glowingly described by Thomson:—

> "Meanwhile you gain the top from whose fair brow
> The bursting prospect spreads immense around," &c.

† First Impressions of England and its People, by Hugh Miller; London, 1847, p. 111.

‡ Silurian System, p. 468.

and appear in various detached points, near Dudley. The largest mass constitutes Rowley Hill, a ridge two miles and a half long, and one mile wide, extending from Rowley Regis to the southern suburbs of Dudley. This trap rock, known locally as the *Rowley-rag*, is a hard, fine-grained, crystalline green-stone, being an admixture of grains of hornblende with small crystals of felspar and quartz. This mineral appears in a slender columnar form in Pearl Quarry, near Timmin's Hill, at Rowley.



1, 1, 1. Trap rock. 2, 2. Quartz rock: Silurian strata altered from contact with the trap. 3. Caradoc sandstone. 4. Carboniferous limestone. 5, 5. Coal measures. 6. Wenlock shale,

LIGN. 175.—SECTION THROUGH THE WREKIN TO LITTLE WENLOCK.
(*Sil. System, pl.* 29, *fig.* 17.)

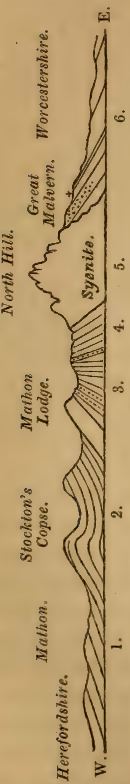
But one of the most remarkable examples of erupted trap in this part of England, is that which has formed the hill called the Wrekin, near Wellington in Shropshire, on the north-west flank of the coal-field of Coalbrook Dale; and which must have taken place after the accumulation of the Silurian strata, as the latter were evidently thrown into inclined positions before the carboniferous were deposited.* At a subsequent period, and long after this consolidation, the coal-measures were in their turn pierced and traversed by other intruded masses of igneous rock, differing in mineral matter, but erupted in contiguous lines of fissure, parallel to that of the Wrekin.

* The erupted trap forming Barrow Hill (*ante*, p. 686) is another instructive example of this phenomenon.

The WREKIN is an elliptical hill, about a mile and a quarter long, its highest summit being 1,320 feet above the level of the sea. It is composed of igneous rocks, having on its flanks various members of the Silurian and Carboniferous systems, as shown in the section, *Lign.* 175. The sedimentary deposits within the influence of the erupted volcanic rocks have undergone considerable alteration; the sandstone being changed into granular quartz rock, much of which is pure white quartz, with particles of decomposed felspar: in some places this rock becomes a brecciated aggregate.

These igneous masses are various modifications of pink and deep red syenite, consisting of compact felspar with white quartz, and disseminated chlorite: in some parts the mass is made up of felspar with green earth and veins of carbonate of lime. To the south-east of the Wrekin, bosses of a basaltic green-stone, of irregular shape, appear around the village of Little Wenlock (*Lign.* 175).

The invaluable work to which I am indebted for most of the interesting facts thus briefly noticed, should be referred to for full details of the geological structure and relations of the deposits under review. The eminent author considers this district of Shropshire as affording unequivocal evidence of the alternate activity and repose of volcanic action, during very long periods in the palæozoic ages; and that the following sequence of geological events is clearly established: —1, that volcanic grits were formed during the deposition of the Lower Silurian strata:—2, the Upper Silurian rocks and Devonian sandstone were accumulated tranquilly, without a trace of contemporaneous eruptions:—3, after their consolidation, the last-mentioned deposits were dismembered, and set upon their edges by vast outbursts of intrusive trap:—4, the Carboniferous system was deposited after the older strata were upheaved: and 5, that subsequent dislocations, including some of the most violent with which we are acquainted, took place after the deposition of the coal measures and Triassic sandstone.*



1. Devonian beds. 2. Ludlow rock. 3. Wenlock strata. 4. Caradoc limestone and grit, overturned. 5. Syenite. 6. Triassic deposits.

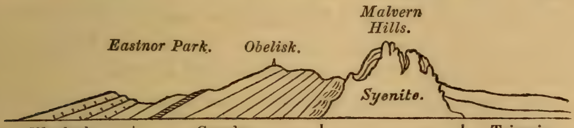
Lign. 176.—Section through the Malvern Hills. (*Sil. Syst. pl.* 36.)

16. The Malvern Hills.—In Worcestershire, the different members of the Silurian system are well developed, and though occupying a narrower zone than in Shropshire, constitute a continuous band for a distance of between twenty and thirty miles; viz. from the northern end of the Abberley Hills, to the southern extremity of the Malverns; "and though the strata are dislocated, and even through a course of four miles entirely *reversed*, yet they maintain a prevalent inclination to the west, and dip beneath the Old Red-sandstone of Herefordshire. Emerging through the Silurian deposits, and forming a buttress on their eastern flank, are certain igneous rocks, which, in the Abberley Hills, protrude only at intervals through the dislocated strata, but in the Malverns constitute a narrow ridge of syenite, rising to some height

* Silurian System, p. 235. It would be foreign to the object of these Lectures to enter more fully on the highly interesting phenomena presented by those districts in Staffordshire, Shropshire, Worcestershire, and Pembrokeshire, which have been the theatre of submarine volcanic eruptions, as proved by the ridges and protrusions of igneous rocks; but I would fain hope that the intelligent reader may be induced, from what has been stated, to refer to the "Silurian System" of Sir R. Murchison, which contains a lucid account of the facts thus

above the Silurian deposits;"* as represented in *Lign.* 176, 177.

The Malvern Hills are situated in the south-western part of Worcestershire, and consist of an uninterrupted chain about nine miles long, and two wide, the highest summits attaining an altitude of nearly 1,500 feet. This outline, when viewed from a distance, as for example, from the heights above Cheltenham, is very striking, and characteristic of their geological structure. The three highest points are the Herefordshire and Worcestershire beacons, and North Hill (*Lign.* 176), formed by the protruded syenitic rocks, which are the nucleus of this mountain range.†



Lign. 177.—Section of the Malvern Hills.

(*Sil. Syst. pl.* 36, *part of fig.* 8.)

In passing from Herefordshire to Worcestershire, in a line from west to east (see *Lign.* 176), the Devonian or Old Red strata first appear, and are succeeded by the upper Silurian, viz. the Ludlow and Wenlock deposits: next follow beds of Caradoc sandstone, and we then arrive at the protruded peaks of igneous rock, and descend over triassic strata to the plains of Worcestershire. The relative position of the rocks and strata is shown in the annexed diagrams (*Ligns.* 176, 177). The entire succession of the Silurian series, between the Syenite of the

imperfectly noticed, illustrated by highly picturesque geological sketches, and sections.

* Silurian System, p. 410.

† A very interesting memoir on the mineralogy of the Malvern Hills, by Leonard Horner, Esq., was published in vol. i. of the Geol. Trans. p. 281.

Malverns and the Old Red-sandstone, is beautifully exposed in a transverse section from Midsummer Hill to Ledbury.

But there is one feature in the geology of the Malvern Hills that demands particular notice. The Silurian strata in immediate contact with the Syenite (as, for example, near Mathon Lodge) are partly bent back, as shown in the section, *Lign.* 176, in which the Wenlock limestone (3), is seen removed from the syenite, and unaffected; while the Caradoc limestone and grit (4), are overturned, and dip in an opposite direction.*

In the Abberley Hills, the same phenomenon appears in a more striking point of view; and through a range of four or five miles, the Devonian, Ludlow, and Wenlock strata are completely inverted, the newer formations being overlaid by the older, "and so symmetrical is this retroversion in some parts, that any geologist, who had not previously made himself acquainted with the true order of superposition, would naturally conceive the Wenlock limestone to be younger than the Ludlow rock, and the latter of newer origin than the Old Red-sandstone."†

The Lickey Hills, which are situated about three miles from the southern extremity of the Dudley coal-field, and consist of a narrow ridge of quartz rocks, about three miles in length, and four or five hundred feet high, are referred by Sir R. I. Murchison to the Caradoc sandstone; a lower zone of the Silurian system than is apparent in any other part of this district. As in the case of the altered sandstones on the flanks of the Wrekin (*ante*, p. 772), the quartz rock of the Lickey gradually passes into a fossiliferous sandstone, full of the characteristic organic remains of the Caradoc strata.‡ A mass of trap, being the pro-

* See Plate 36, of Sil. Syst. † Sil. Sys. p. 420, 421.

‡ The quartz pebbles, so largely distributed over this part of England, and extending into the valley of the Thames, are waterworn fragments of the rocks composing this ridge; see *ante*, p. 212.

longation of that of the Clent and Abberley Hills, forms the nucleus of the ridge, and appears in the point called Lickey Beacon, on the northern end of the Bromsgrove Lickey Hills, which consist, in great part, of triassic strata.*

The Valley of Woolhope, which lies to the west of the southern extremity of the Malverns, about three or four miles from Hereford, is a remarkable instance of what geologists term a valley of elevation; being a dome-shaped protrusion of Silurian rocks through the Devonian deposits, of which the surrounding region consists. This elevated mass of strata is of an oval form, being six miles long, and four wide. Within this area, the strata of the three upper Silurian series are thrown up into concentric and conformable masses, each dipping outwards from a common centre, and the whole passing beneath the Old Red-sandstone. The central nucleus consists of quartzose grits belonging to the Caradoc sandstone group. The trenches surrounding the central mass have been produced by the degradation of the more perishable beds, and the denudation of the harder rocks.†

I must not conclude this brief sketch of the geological phenomena of the British Silurian system, without mentioning that evidences of *sub-aerial* volcanoes have been discovered by Sir H. De la Beche, in Worcestershire and Pembrokeshire. During the period when the Llandeilo flags and their equivalents were accumulated over the area extending from the Malverns to Pembrokeshire, volcanic vents existed, whence molten matter and ashes were ejected, and became intermingled with the detrital accumulations of the period. The volcanic ashes were mixed up with the gravels and sands that are now in the state of conglomerates and sandstones, and accumulated in beds that are interstratified with the mud and sand. These igneous

* Silurian System, p. 493.

† Ibid. chap. xxii. p. 428.

products were erupted prior to the granite of those regions. Even in the Devonian strata near Tavistock, and in South Devon, volcanic ash is intermingled with the argillaceous slates and limestones.*

17. SILURIAN STRATA OF EUROPE AND AMERICA.—From the short period that has elapsed since the establishment of the Silurian System, it is scarcely possible accurately to determine the position of all the foreign sedimentary deposits, formerly known to geologists by the general term of Transition rocks; but so far as recent observations have ascertained the characters and relations of the most ancient fossiliferous strata on the Continent, they are all referable to the same geological period as the Silurian formations of England.

In France the oldest palæozoic rocks are unquestionably Silurian. In Bohemia, and around Prague, similar strata are largely developed, and abound in trilobites, and other characteristic fossils.†

Throughout Scandinavia crystalline rocks occupy the surface of the country to a vast extent, and are covered in many places by sedimentary strata containing Silurian fossils. In Christiania, Lower Silurian deposits occupy a long trough of primary rocks; and the little islands in the Bay contain Upper Silurian strata.‡

Throughout a large part of the province of Skaraborg, in the south of Sweden, the Silurian strata are perfectly horizontal; the different subordinate formations of sandstone, shale, and limestone, occurring at corresponding heights, in hills many leagues distant from each other, with the same mineral characters and organic remains. It is clear that they have never been disturbed since the time

* Memoirs of the Geological Survey of Great Britain.

† Barrande, on the Silurian System of Bohemia. See Geological Journal, vol. iii. part ii.

‡ See Sir R. I. Murchison's Memoir on the Geology of Sweden, in Geological Journal, vol. iii. part i.

of their deposition, except by such gradual movements as those by which large areas in Sweden and Greenland are now slowly and insensibly rising above, or sinking below, their former level.*

In Russia, the lower division of the Silurian system is characterized, as elsewhere, by the abundance of Orthes, Leptænæ, and other brachiopodous shells, Orthoceratites, and Trilobites; and the upper, by large masses of corals, especially of Favosites, Catenipora, &c.; and the Devonian strata teem with remains of the typical species of fishes, and Spirifers, Leptænæ, and Serpulæ (*ante*, p. 757). Throughout the immense extent of Central Russia, forming nearly one-half of the European continent, there are no intrusions of igneous rocks; and the whole of the deposits, from the lowermost to the uppermost, are but little altered, and in many instances are unsolidified; yet each group contains the same characteristic organic remains as in England. But in the Ural mountains and Siberia, the formations of the same age are thrown up into mural masses, broken into fragments, impregnated with mineral matter, and exhibit every variety of metamorphic action. Yet a clear distinction may nevertheless be drawn between these

* Mr. Lyell's Elements of Geology, vol. ii. p. 175. On these phenomena Mr. Lyell thus comments:—"These facts are very important, as the more ancient rocks are usually much disturbed, and horizontality is a common character of the newer strata. Similar exceptions, however, occur in regard to the more modern or tertiary formations, which, in some places, as in the Alps, are not only vertical, but in a reversed position. These appearances accord best with the theory which teaches, that, at all periods, some parts of the earth's crust have been convulsed by violent movements, which have been sometimes continued so long, or so often repeated, that the derangement has become excessive: while other spaces have escaped again and again, and have never once been visited by the same kind of movement. Had paroxysmal convulsions ever agitated simultaneously the entire crust of the earth, as some have imagined, the most ancient fossiliferous strata would nowhere have remained horizontal."—*Ibid.* p. 176.

pseudo-igneous masses and the true ancient primary rocks on which the Silurian strata of Scandinavia rest.*

In North America a similar succession prevails ; and we have thus proof that the modification, extinction, and renewal of species, are attributable neither to the alteration in the course of currents, nor to the elevations or depressions of the ocean-bed, nor to other more or less local causes, but depend on some general laws which govern the entire animal kingdom. It is, too, most remarkable, that in Russia where the deposits have gone on through immense periods without interruption, there are few species which pass from one system into another.

The Silurian system of North America is divided, as in England, into two groups, which are thus named :—

UPPER SILURIAN.	Hamilton series. Hilderberg series. Onandaga Salt group Niagara and Clinton group.
LOWER SILURIAN.	Hudson river, Utica, &c. Trenton limestone. Potsdam sandstone.

Silurian strata constitute the grand ranges of the Alleghanies ; they appear at the Falls of Niagara, and in the Canadas and Nova Scotia, resting on gneiss and granitic rocks, like the equivalent deposits in Scandinavia. The White Mountains of America are altered Silurian rocks.†

18. FOSSILS OF THE SILURIAN SYSTEM.—The remains of upwards of 800 species of animals have been discovered

* "Whilst Siberia and the Urals were above the waters, Russia in Europe must have been beneath them ; a conclusion which seems necessary in order to render explicable upon rational grounds the phenomena of the great Scandinavian drift, by which all the low countries of the north have been covered by boulders and far-transported materials."—*Geology of Russia.*

† The admirable Geological State Surveys of North America, by Professors Hitchcock, Rogers, Hall, &c. contain full particulars of the palæozoic strata and their organic remains.

in the Silurian deposits, and of these, one hundred are also present in the Devonian formation ; but only fifteen species are common to the whole palæozoic epoch, and not one is known in any of the newer deposits. These remains almost exclusively belong to the invertebrata, the relics of fishes being comparatively rare ; the large development of this class of vertebrated animals in the Devonian strata above, is a remarkable zoological character of that epoch, for the general forms of the Silurian fauna, with this exception, are also found in that system.

Vegetables.—In England, and on the Continent of Europe, imperfect traces of *Fucoids* are the only vegetable remains hitherto observed in strata older than the Devonian ; nor has any coal or carbonaceous matter been discovered, except small nests of culm or anthracite. The most ancient shales and sandstones of Scandinavia and Russia contain fuci only, and these rocks are considered by Sir R. Murchison as forming the limit where the phenomena of organization stop.* For as these lowermost Silurian deposits with fucoids, rest upon pre-existing crystalline rocks without fossils, it has been assumed that they indicate the first appearance of organic creation: an inference which, in the present state of our knowledge, is in my opinion wholly inadmissible.

Mr. Lyell, with his accustomed sagacity, has taken a more just and comprehensive view of this question. He observes,† that from the absence of all terrestrial vegetation and fresh-water shells, it has been inferred that but a small extent of dry land, if any, existed at the Silurian epoch. " But if we colour on a map of the globe those spots over which the Silurian strata have been hitherto traced, and consider the insignificance of their extent in comparison with the surface of our planet, we shall instantly perceive

* Geology of Russia. † Elements of Geology, vol. ii. p. 172.

the rashness of such generalizations." But though the Silurian strata in Europe contain no vegetables but fucoids, and these also abound in the equivalent deposits in North America,* yet we have undoubted evidence that in the "Hamilton group" of the United States—a series of beds that corresponds in many of its fossils with the Ludlow rocks of England—plants allied to the common carboniferous type, as for example the *Lepidodendra*, are abundant ; and in the lowest Devonian strata of New York, the same plants occur associated with ferns.†

Mr. Lyell also remarks, that as there is every reason to conclude that the Silurian deposits were generally formed far from land, this circumstance would alone explain the extreme scarcity of terrestrial plants. The observations of Professor E. Forbes on the physical conditions under which the Silurian strata were deposited, tend to confirm this opinion. This profound observer infers that the Silurian seas, in those areas hitherto examined, were at first very deep and tranquil, and afterwards that certain areas became shallower, either from the accumulation of detritus, or the partial elevation of the sea-bottom ; and this opinion is based upon the following data, namely, the small size of most of the conchifera—the paucity of spiral univalve shells—the great number of floating mollusca, such as the Bellerophon (*Medals*, p. 476), Orthoceras (*Medals*, p. 484), &c.—the abundance of brachiopodous shells (*Spirifer*, *Leptæna*, *Orthis*, &c.)—the extreme rarity of the remains of fishes—the deep-water forms of most of the fucoids—and lastly, the absence of terrestrial plants.‡

19. Silurian Zoophytes and Mollusca.—The fossil corals, crinoidea, and shells, in many of the Silurian rocks, are so numerous, and comprise so many interesting forms,

* See Medals of Creation, p. 105.

† Mr. Lyell's Travels in America.

‡ Ibid. p. 57.

that a reference to works expressly devoted to the subject can alone convey an accurate idea of this first, and most ancient, fauna of our planet, of which any vestiges have hitherto been obtained.*

Of the corals, the *Catenipora* or chain-coral (*ante*, p. 644), *Cyathophyllum* (p. 641), *Astræa*, and many large species of *Porites*, *Strombodes*, &c. are among the prevalent forms: and are often aggregated and cemented together into large masses of limestone, on the surface of which the stars or cells of the corals appear in relief. The slabs of Dudley limestone, embossed with these fossils, must be familiar to every intelligent observer.

The *Graptolites*, which are extinct zoophytes allied to the *Pennatulæ*,† and *Tentaculites*, appear throughout these deposits, especially in the lowermost. They occur in the equivalent strata of Sweden, Norway, Russia, and North America.

The *Crinoidea* consist of several genera, as *Cyathocrinus*, *Actinocrinus*, *Hypanthocrinus*,‡ &c. which also abound in the upper palæozoic deposits; and some that are peculiar, as *Echinosphærites*, and the family of *Cystideæ* (*ante*, p. 656), that includes several genera, which, according to the observations of M. Von Buch, are only known in the Silurian system.

Mollusca. Of the simple bivalves, species of *Arca*, *Cardiola*, *Cardium*, *Modiola*, *Mytilus*, *Nucula* and *Avicula*, are met with; proving that these genera, which now

* The beautiful and accurate plates by Mr. Scharf, in Sir R. Murchison's Silurian System, contain representations of a large proportion of the British species. Many are figured in the Geol. Transactions, and in the Palæontological Journal, and in Sowerby's Mineral Conchology: and in Professor Phillips' Figures and Descriptions of the Palæozoic Fossils of Cornwall, Devon, and West Somerset.

† Medals of Creation, p. 290.

‡ A beautiful new species of this genus from the Wenlock limestone of Walsall, is figured in the London Geological Journal, pl. 21.

swarm in our seas, also existed in the most remote periods of which we have any traces of organic life.

Species of the living genus *Chiton*, have recently been found in the Silurian rocks of Ireland.*

But it is the brachiopodous mollusca, that constituted the great mass of the population of the Silurian seas, and were rivalled only in numbers and variety by the extinct crustaceans, the Trilobites. The ancient types, as *Atrypa*, *Calceola*, *Leptæna*,† *Pentamerus*, and *Spirifer*, are associated with species of *Lingula*, *Orthis*, and *Terebratula*,—genera which still exist. Twenty-five species of Terebratula, and thirty-eight species of Orthis, and seven of Lingula, have been obtained from the British strata alone.

The Potsdam sandstone, the most ancient fossiliferous rock of New York, is in many places divided into laminæ by the remains of innumerable shells of the genus Lingula. They are in such profusion as to form black seams like mica, and are accompanied with another small placunoid shell, which is also associated with a small species of Lingula in the lowest beds of the English Silurian series in Brecknockshire. Here, then, in the most ancient term of organic life is a shell belonging to a genus not extinct, and very like a species still living.‡

In fact, throughout the palæozoic deposits the brachiopodous mollusca abound; and hence we may infer the immense development of this family in the ancient seas. Nearly half the Silurian shells figured by Sir R. I. Murchison in his Geology of Russia, belong to brachiopoda. The genera Orthis, Spirifer, Leptæna, &c. are the most common forms

* See a notice of a fossil Chiton from the Silurian rocks of Ireland, by Mr. Salter, Geological Journal, vol. iii. p. 48.

† Three species of Leptæna have recently been discovered in the *Lias* of France.

‡ Mr. Lyell's Travels in America, p. 157.

in the oldest deposits; but a brachiopodous shell with free valves, and without an articulated hinge, is the lowermost term of animal life, according to our present palæontological knowledge. A species of *Ungulite* or *Obolus* (a small orbicular horny shell) occurs in the inferior limits of the fossiliferous deposits in Russia and Europe;* occupying the same geological position as the Lingulæ, in the American and Silurian beds above cited.

Of the pteropodous mollusca,† there are several species belonging to two genera, named *Conularia*, and *Creseis*.‡

20. Silurian Gasteropoda and Cephalopoda.—Of the Gasteropoda or simple univalve mollusca, the *Euomphalus* (*ante*, p. 736) appears to be the most ancient type, and several species are common both in the Silurian and Devonian formations; but these are associated with shells of the existing genera of *Turbo*, *Turritella*, *Trochus*, *Pleurotomaria*, and *Natica*.

Cephalopoda. The cephalopodous mollusca are represented in the Silurian deposits by several genera, of which the *Orthoceras*, and allied forms, are the most numerous and characteristic. *Goniatites* and *Bellerophon*, so frequent in the Devonian and Carboniferous formations, though present, are comparatively rare. Of the *Orthocerata* upwards of thirty species of the genus *Orthoceras* have been obtained from the British strata. The *Actinoceras*, distinguished from the former by the remarkable structure of the siphunculus, the tube of which is surrounded by verticillate processes, has hitherto been observed in the Silurian deposits only, occurring in the limestone of Lake Huron, and in that of Ireland.§

* Geology of Russia, vol. ii. p. 292.

† Medals of Creation, p.367.

‡ Quarterly Geological Journal, vol. i. p. 146, contains a notice on some fossil species of *Creseis*, by Professor Forbes.

§ See Mr. Lyell's Elements of Geology, p. 174.

Some specimens of Orthoceras attain a large size, being nearly three feet in length, and having seventy septa.

The *Lituites*, another modification of this family, bearing a general resemblance in form to the shell of the recent Spirula, are also found in this formation.*

21. SILURIAN ANNELIDES AND CRUSTACEANS. — The class of articulated animals termed *Annelida*, consisting of worms with bodies formed of rings or annular segments, and having red blood, of which the Earth-worm and Leech are familiar examples of the naked forms, and the Serpulæ of those protected by shells, traces occur in the Silurian deposits: and of the naked, flexible, soft-bodied marine worms, the *Nereis* and the *Gordius*, the distinct imprints of several species have been discovered on the surface of the limestones.†

Trilobites.‡ But the most extraordinary feature in the Silurian fauna, is the abundance and variety of a peculiar family of Crustaceans, of which there are no living representatives, and which is restricted to the palæozoic formations, and almost exclusively to the most ancient fossiliferous deposits; for while the Silurian rocks teem with the relics of hundreds of species, but few, comparatively, occur in the Devonian and Carboniferous; while the prevalent modern forms of Crustaceans, the Lobsters, Crabs, &c. are entirely absent.

* Some Orthoceratites from the blue marlite of Cincinnati, are partially surrounded by an oval bilobed body, twice the diameter of the enclosed shell; and which is supposed by Mr. I. G. Anthony, who first observed these fossils, to be the soft parts of the animal; but in the specimens sent to the Geological Society of London, these bodies appear to be extraneous, and to have no organic connexion with the Orthoceratites. Specimens are figured in the Quarterly Geological Journal, vol. iii. p. 256.

† Medals of Creation, p. 523.

‡ *Trilobites*, signifying three-lobed, from the general form of the carapace, or shell.

These remarkable crustaceans, which constituted the great mass of the population of the palæozoic seas, have the body protected by a strong dorsal case or shell composed of numerous annular segments, or arches, and which is generally divided into three lobes by two longitudinal furrows or depressions. The head and abdomen are each covered by a single piece. The eyes of most of the genera are very large and reticulated, consisting of numerous distinct facets or lenses, as in other crustaceans, and are implanted on the cephalic buckler. No traces of pats, feet, or swimmers, have been detected, and it is therefore sup-

LIGN. 178.—TRILOBITE IN SILURIAN LIMESTONE; FROM DUDLEY.

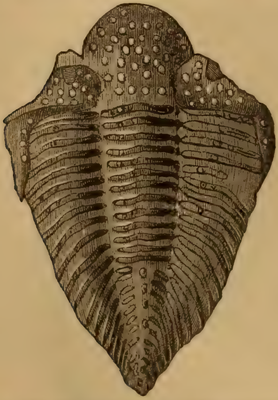
(*Calymene* Blumenbachii.*)

posed that these appendages were composed of a soft and perishable substance.†

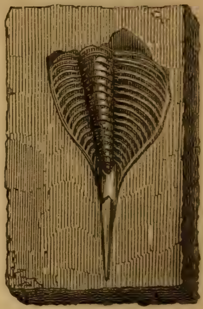
* *Calymene*, signifying concealed: in allusion to the non-discovery of legs or antennæ.

† Consult Medals of Creation, pp. 552-556.

One of the most common species of Trilobite is that known as the Dudley fossil *Locust*, and which has long attracted the attention of collectors;* this crustacean is found either attached by the under surface to the rock, as in *Lign.* 178, or coiled up like an Oniscus, or wood-louse.† The Trilobites vary exceedingly in form and magnitude; some species not exceeding a few lines, while others are eighteen or twenty inches in length. Some kinds, as the Calymene, could coil themselves into a ball like the millepedes; while others had the central segments alone moveable, as in *Asaphus* (*Lign.* 179); and many have a tail, or post-abdomen (*Lign.* 180). In some species this tail is



LIGN. 179.—TUBERCULATED TRILOBITE, FROM DUDLEY. (*Asaphus*‡ *tuberculatus.*)



LIGN. 180.—ASAPHUS CAUDATUS, FROM DUDLEY.

a styliform process, as in the recent Limulus, and thrice as long as the body. In the Silurian limestones of North America, a gigantic trilobite, named *Isotelus*, from both extremities of the body having a similar contour, is often

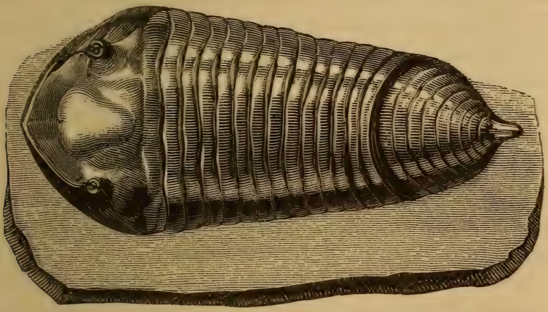
* This Trilobite was figured and described by Lhwyd, in 1698.

† Medals of Creation, p. 553, fig. 4.

‡ *Asaphus*, signifying obscure.

met with; the detached segments of which might easily be mistaken for remains of Chelonian reptiles.* The body is of an oval shape, and the posterior angles of the head are rounded: the thorax is composed of eight segments.

A remarkable kind of Trilobite occurs in the Ludlow limestone, and has been named *Homalonotus* (*Lign.* 181) by Mr. König, from the almost entire absence of the lateral furrows. The surface is scabrous, and the thoracic portion of



LIGN. 181.—TRILOBITE FROM THE LUDLOW ROCKS.

(*Homalonotus delphinocephalus; reduced from Pl. VII. Sil. Syst.*)

the carapace, which is but obscurely lobed, consists of thirteen segments; the abdominal region is distinct from the thoracic, and formed of nine rings: it terminates in a prolonged point. In the late work of an eminent naturalist, M. Burmeister,† the trilobites are arranged under fifty genera, comprising 250 species; many of the species named by former observers being grouped together, from their proving to be the same animals in various states of metamorphosis. The

* Dr. John Locke, of the Medical College, Ohio, who first developed the structure of this gigantic Trilobite, has obliged me with specimens that leave no doubt as to the fidelity of his model of the perfect form of the original, of which there is a specimen in the British Museum, nearly two feet in length.

† Die Organisation der Trilobiten: Berlin, 1843.

Trilobites are supposed by M. Burmeister to have inhabited deep water, near the sea-coasts, to have swam with facility, and with the back undermost. As no traces of legs have been discovered, it is probable that they possessed soft perishable paddles, bearing branchiæ. Their food consisted of marine animalcules; they were gregarious, grouping together in innumerable multitudes. Like other articulata, they cast their shells or cases; hence the abundance of their exuviæ. Mr. Burmeister is of opinion that they were most nearly allied to the existing family of crustaceans, the *Phyllopoda.*

The geological distribution of the different genera of Trilobites in the subdivisions of the Silurian system, though presenting some anomalies, is considered by Sir R. Murchison as well defined. According to this eminent geologist, the *Homalonotus* is characteristic of the highest zone, or Ludlow rocks, being most abundant in the Wenlock and Ludlow limestones: the *Calymene* ranges through those deposits, but is particularly abundant only in the lower limestones, beneath which it has not been observed. The *Asaphus caudatus* extends from the Ludlow rock to the base of the Wenlock formation: both these forms are, therefore, characteristic of the Upper Silurian. In the Lower Silurian the genera Trinucleus,* Agnostus,† and Ogygia,‡ are the prevailing organisms of this class.§

22. VISUAL ORGANS OF THE TRILOBITES.—The eyes of the Trilobites resembled in structure those of crustaceans and insects, which are composed of a vast number of elongated cones, each having a crystalline lens, pupil, and cornea, and terminating on the extremity of the optic nerve. Each organ of sight is, therefore, a compound instrument, made

* Medals of Creation, p. 558. A memoir, On the Structure of the *Trinucleus,* by Mr. Salter, is published in Geol. Journal, vol. iii. p. 251.

† Ibid. p. 565. ‡ Ibid. p. 559.

§ See, On the Geological Distribution of Fossil Crustaceans: Medals of Creation, p. 563.

up of a series of optical tubes, or telescopes, the number of which in some insects is quite marvellous. Thus, each eye of the common house-fly is composed of eight thousand distinct visual tubes; that of the dragon-fly, of nearly thirteen thousand; and of a butterfly, of seventeen thousand.

That any traces should remain of the visual organs of animals which existed at so remote a period seems at first incredible; but there are no limits to the wonders which Geology unfolds to us.* The Trilobite, like the Limulus, was furnished with two compound eyes, each being the frustrum of a cone, but incomplete on that side which is opposite to the other. In the Asaphus (*Lign.* 179), four hundred spherical lenses have been detected in each eye; but in general the lenses have fallen out, as often happens after death in the eyes of the common lobster. "Thus," observes Dr. Buckland, "we find in the trilobites of these early rocks, the same modifications of the organ of sight as in the living crustaceans. The same kind of instrument was also employed in the intermediate periods of our geological history, when the secondary strata were deposited at the bottom of a sea inhabited by Limuli (*ante*, p. 738), in those regions of Europe which now form the elevated plains of central Germany. But these results are not confined to physiology: they prove also the ancient condition of the seas and atmosphere, and the relation of both these media to light. For in those remote epochs, the marine animals were furnished with instruments of vision in which the minute optical adaptations were the same as

* The structure of the eye of the Trilobite was, I believe, first noticed by that accurate observer, Mr. Martin, the author of *Petrif. Derbiensia.* In the work of my friend, M. Brongniart (*Histoire Naturelle des Crustaces Fossiles, par A. Brongniart et G. A. Desmarest,* 1 vol. 4to. with Eleven Plates, Paris, 1822), the eye of the Trilobite is beautifully represented. In Dr. Buckland's Bridgewater Essay, the subject is ably elucidated, and placed before the reader in a striking point of view.

those which now impart the perception of light to the living crustacea. The mutual relations of light to the eye, and of the eye to light, were, therefore, the same at the time when crustaceans first existed in the bottom of the Silurian seas, as at the present moment."*

23. FISHES OF THE SILURIAN SYSTEM.—Of vertebrated animals, the relics of a few species of fishes belonging to five or six genera of the placoid order (*ante*, p. 340), are the only vestiges hitherto obtained from the immense series of strata composing the Silurian system. Even imprints of the feet of a higher order of animals, Reptiles, of which the carboniferous rocks afforded indications, are altogether wanting in these most ancient fossiliferous deposits. Until lately, Ichthyolites were only known in the upper Silurian; but I learn from Sir R. Murchison, that the same species of Cestracion (*Onchus Murchisoni*) that occurs in the upper, has recently been found in the lower deposits: the same general organic type, therefore, prevails throughout the system.

These ichthyolites consist of teeth, portions of the skin or shagreen, and dorsal rays or spines, of fishes of small size.† They have chiefly been found in the upper Ludlow rocks, in which there is a bone-bed, a few inches thick, almost wholly made up of animal detritus, consisting of the scales, teeth, fin-bones, coprolites, &c. of small fishes: this deposit resembles the bone-bed at the base of the Lias in Somersetshire (*ante*, p. 529). In the Wenlock shale, numerous teeth and fin-bones of fishes of the Cestracion family have been discovered.

24. THE CUMBRIAN OR SCHISTOSE SYSTEM. — The Silurian system is succeeded by a vast series of strata of a slaty character, which are destitute of any distinct assemblage of organic remains, although fossils occur in some of the uppermost rocks. These deposits extend over a great

* Bridgewater Essay. † See Pl. IV. of Silurian System.

part of Cumberland, Westmoreland, and Lancashire, reaching to elevations of three thousand feet, and giving rise to the grand scenery of the Lakes and of North Wales. Similar strata flank the Grampians, and the range of Lammermuir, and occur in Argyleshire, and in the west of Scotland. Schistose rocks, referable to the Silurian and Cumbrian systems, extend through the country from the sea-coast of Wigton washed by the Irish sea, over Dumfriesshire and Berwickshire, to the North Sea beyond Berwick-upon-Tweed; being flanked here and there by Devonian deposits. In the Shetland Isles, which, with this exception, consist of primary rocks, the southern prolongation is made up of slaty deposits, bordered by Old Red strata.

The coast of Ireland, opposite to that of Wales and Cumberland, is formed by Silurian and Cumbrian strata, which spread over Wexford, and part of Waterford and Wicklow; an enormous intrusion of igneous rocks rising up in Carlow, and reaching to the shore of Dublin Bay, at Kingstown. From Drogheda Bay to Belfast Lough similar deposits appear, covering a great portion of Armagh, Monaghan, and Louth; the whole sinking westward beneath the vast region of mountain limestone, which occupies more than one-half the entire area of Ireland.*

Wales may be described as a grand slate formation, with a considerable expansion of indurated conglomerate or Greywacké. In Charnwood Forest† slate rocks appear beneath the triassic strata, and they form a considerable part of Anglesea and the Isle of Man.

* Mr. Knipe's Geological Map of the British Isles presents a *coup d'œil* of the geographical distribution of these formations over England, Scotland, and Ireland.

† The Charnwood Forest hills are syenitic rocks protruded through schistose strata, before the deposition of the triassic sandstones and clays, which are disposed in horizontal layers around their base. See Medals of Creation, p. 974.

In Cornwall schistose rocks (locally termed *killas*) largely predominate, but they are referable to very distinct geological epochs; the newest belonging to the Devonian; the next in age to the Silurian; while the most ancient, if they can be separated from the latter, would rank with those of Cumberland. But in the present state of the question as to the most natural classification of the oldest fossiliferous strata, it is impossible to arrange with precision the slate rocks of particular regions.

The following tabular arrangement explains the relative position and characters of the subdivisions of the Schistose strata of the Principality, adopted by Professor Sedgwick:—

THE CAMBRIAN OR SLATE ROCKS OF NORTH WALES.

(*Commencing with the uppermost.*)

1. *Plynlymmon rocks.*—Greywacké and slate, with beds of conglomerates. Thickness, several thousand yards.
2. *Bala limestone.*—Dark limestone, associated with slate, containing a few species of shells and corals.
3. *Snowdon rocks.*—Slates, fine-grained, and of various shades of purple, blue, and green. Fine and coarse grauwacké and conglomerate. A few organic remains. Thickness, probably several thousand yards.

The upper dark-coloured schists contain a few corals and fuci; and Professor Phillips has discovered in the strata of Snowdon two species of corals (*Cyathophyllum*), and six of shells belonging to the family of *Brachiopoda*. In the lower series, fossils are of rare occurrence; and in its few species of fuci, corals, and shells, we see the last traces of organization, and arrive at the extreme limits of the animal and vegetable kingdoms of the ancient world, so far as are cognizable by organic remains.

The strata of Cumberland and the Lake districts, form a system, which is thus defined by the same eminent philosopher.

The Cumbrian System.

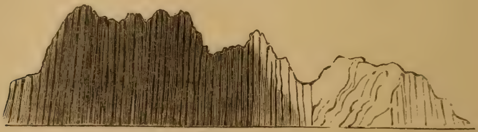
(Commencing with the uppermost.)

1. *Upper slate of Kendal.*—Greenish grey flagstones, grits, and slates, with Upper Ludlow fossils.
2. *Ireleth slates.*—Coarse slates, flags, and grits; with calcareous slates and limestones: containing Lower Ludlow fossils.
3. *Coniston grits and flagstones:* with Upper Silurian species of fossils.
4. *Coniston limestone and slate,* with Lower Silurian fossils.

As no assemblage of organic remains distinct from that of the Silurian system has been discovered, a zoological line of separation cannot be drawn between the Silurian and Cambrian deposits; and Sir R. Murchison now classes the whole of the fossiliferous slates with the Lower Silurian; employing the term *Cumbrian* to designate certain schistose rocks in the Lake districts, which are destitute of organic remains, and underlie the fossiliferous beds in an unconformable position. On the other hand, Professor Sedgwick considers the zoological characters both of the C*a*mbrian and C*u*mbrian groups, as sufficiently distinct from the Silurian, to warrant their establishment as a separate system, apart from their mineralogical structure. The discovery of other peculiar types of organic remains in the slate rocks, can alone determine the propriety of their separation.* Without presuming to decide upon this question, I shall endeavour to avoid confusion, by using the term C*u*mbrian to designate the lowermost and most ancient slate rocks, in which very few, if any, organic remains have been detected, and those only in the uppermost zone; and restrict the name C*a*mbrian to the slate rocks of North Wales.

* The arguments of these eminent geologists in support of their respective opinions, are fully stated in Vol. III. part i. of the Quarterly Journal of the Geological Society, by Professor Sedgwick, pp. 133—164; and by Sir R. Murchison, pp. 165—179.

25. STRUCTURE OF SLATE ROCKS.—The fineness of grain, general aspect, hardness, and texture of these rocks, are too well known, from the universal employment of slate for economical purposes, to require particular description. The colour usually approaches to blue, grey, green, and a dull purple ; and the texture is very fine, although occasionally the slate passes into sandstone and greywacké. The structure is laminated, and the planes of deposition are commonly well marked ; but there are also divisional lines called *cleavage* planes, which traverse the sedimentary, and give to these ancient argillaceous rocks a very peculiar character.



LIGN. 182.—SLATE ROCKS AT WHITESAND BAY, NEAR ST. DAVID'S, PEMBROKESHIRE.

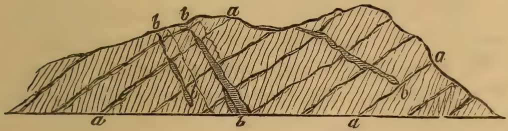
*(The lines of cleavage and stratification coincident.)**

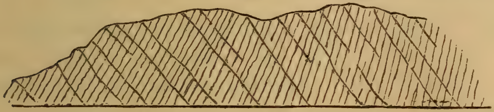
In some instances, the lines of cleavage are in the same plane as those of the strata, as in this section (*Lign.* 182) ; but commonly the cleavage is in a different direction to the stratification, the respective lines crossing each other at various angles. In the quartzose grit and sandstone of Llandovery (*Lign.* 183, *fig.* 1), and in the slate rocks at Whitesand bay, in Pembrokeshire (*fig.* 2), the discrepancy between the lines of deposition and of cleavage is strongly marked. The beds termed greywacké contain fragments and pebbles of clay-slate, and other rocks, and have evidently been indurated by high temperature : in proportion as the extraneous substances are large or small, abundant or scanty, the compound rock is termed a greywacké-con-

* Silurian System, p. 399.

glomerate, or greywacké-slate. Mr. Bakewell observes, that if the red colour were absent in the conglomerates of the Old Red-sandstone, those beds would be in every respect identical with the greywacké of these lower formations.

1





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LIGN. 183.—SECTIONS OF SLATE ROCKS.*

Fig. 1. Section near Llandovery. Quartzose grit and sandstone; *a*, *a*, laminæ of deposit; *b*, *b*, quartzose veins. The highly inclined lines mark the planes of slaty cleavage.

Fig. 2. Section of slate rocks at Whitesand bay, Pembrokeshire; the cleavage and lines of stratification divergent.

26. SLATE ROCKS OF SHROPSHIRE AND CUMBERLAND. —It would be irrelevant to our present purpose to dwell on the mineralogical peculiarities and geographical distribution of strata so widely distributed, and destitute of a characteristic type of organic remains; and I must limit my remarks to a few British localities.† It will

* Silurian System, p. 368, and p. 400.

† From the interest attached to the islands of New Zealand, in consequence of the peculiarity of their fauna and flora, I am induced to add the following general view of their geological structure in this place; the grand physical features of the country appearing to resemble our European districts of schistose strata with intrusive volcanic rocks of ancient and modern date.—" New Zealand forms a group of mountainous islands nearly as large as England and Wales; its geological structure is rendered difficult of discovery

be sufficient to state that the slate rocks almost universally occur on the flanks of the primary masses, rising up into lofty mountain peaks, and dipping beneath the newer sedimentary deposits: thus Skiddaw, Sea-fell, Coniston-fell, and Saddleback in Cumberland, peaks 3,000 feet high, are slate rocks thrown up by a central mass of granite.

The total thickness of the slate system, embracing under that name all the deposits which intervene between the Lower Silurian and the mica-schist, is much greater than that of any other in the geological series, amounting to many thousand yards.

In Shropshire there is a group of the upper Cumbrian rocks, unconformable to the overlying Silurian strata, having evidently been thrown into highly inclined positions before the deposition of the latter. These rocks

by the primeval forests that fringe the coast, or where these have been destroyed, by impenetrable thickets of esculent fern. The fundamental rock is everywhere clay-slate, frequently traversed by greenstone dykes, as at Port Nicholson, Queen Charlotte's Sound, and Cloudy Bay. On the banks of the rivers Eritonga, Waibo, and along some parts of the sea-coast, are horizontal terraces of boulders of trap-rocks, fifty feet high. Anthracite coal crops out in the harbour of Wangarua; and there is a seam of the same mineral intercalated in hard grey sandstone on the east coast of the Northern Islands. On the west coast of the same, the limestone contains a few shells, Pecten, Ostrea, Terebratula, and Spatangus. Veins of copper pyrites occur in the clay slate in the great Barrier Island. The coasts are in many places fringed with recent horizontal sediments consisting of loam, with fragments of wood and tree ferns, &c. The small rocky islands of trachyte off the coast of the Northern Island, also bear marks of wave-action to the height of 100 feet above the present sea-level. In the interior of the Northern Island, there is a lofty central group of volcanic mountains, some of the volcanoes being still in activity; the ancient lava streams appear to have been principally erupted from the base of the craters. The highest are Tongariro 6,000 feet, (*ante*, p. 98) and Mount Egmont 9,000 feet high. The loftiest summits are covered with snow. There are likewise many lakes which appear to occupy ancient craters; and numerous thermal mineral springs, and a cold silicifying stream near Cape Maria."—*Dr. Dieffenbach, Brit. Assoc. Rep.* 1845.

form the *Longmynd* and contiguous ranges of hills, comprising Ratlinghope, Linley, Pontesford, &c., and vary in height from 1,000 to 1,600 feet. The strata consist of hard sandstone, grit, schist, and imperfectly consolidated slates, which are piled up in mural masses, the beds being either vertical, or in very highly inclined positions.* No traces of organic remains have been observed, nor indeed could reasonably be expected, from the altered condition of the strata, produced by the intrusive trap rocks. But cupriferous veins, bitumen, and other minerals, occur in the slates and sandstones, throughout the tract included between the Longmynd and the Stiper stones, especially where there are contiguous masses of trap.† Sir R. I. Murchison concludes his interesting account of the Longmynd hills, with the remark, that the stratified rocks are lithologically similar to, and probably of the same geological age as the so-called greywacké of the Lammermuir and other hills in the south of Scotland. They also correspond with much of the greywacké of the north of Ireland, and with that of large tracts in Somerset and Devon.

The Lake district, so well known to the tourist, may be described as a circular cluster of mountains, the central portion consisting of serrated peaks of schistose rocks, thrown into their present position by granite and other igneous masses which constitute the true geological centres of the mountain groups. The outskirts of this region are chiefly formed by carboniferous deposits; a zone of mountain limestone appears on the east, north, and south, and the western side is bounded by the Irish Sea.

Within the calcareous zone, are several extensive masses of granite, syenite, and porphyry, but the greater part of the region is occupied by stratified deposits of a slaty

* Silurian System, chap. xxi. See the beautiful geological views of these mountain ranges.

† Silurian System, p. 261.

texture, which may be subdivided into the four following formations, commencing with the lowermost :—1. Various crystalline slates, resting immediately on the granite of Skiddaw Forest, and forming the base of the whole stratified series. 2. Black glossy clay-slate, sometimes passing into greywacké. 3. Green quartzose roofing slate, associated, in every variety of complication, with felspathic rocks of porphyritic structure. 4. Greywacké slate, often more or less calcareous, and having subordinate beds passing into impure limestone, full of organic remains.*

The absence of fossils in the older porphyritic slates, may probably be attributable to the obliteration of all vestiges of organic remains from the high temperature to which they have been exposed; or animals may not have been capable of living in an ocean exposed to continual incursions of igneous matter.† But Professor Sedgwick is of opinion, that there is a line in the descending series of strata in our Island, where organic remains entirely disappear; and that this line is by no means co-ordinate with mineral changes induced by igneous action.

27. REVIEW OF THE SILURIAN AND CUMBRIAN SYSTEMS.—In conclusion, I will briefly review the leading phenomena which have been brought under our notice in the course of this Lecture.

The strata comprised in the Silurian system, present all the usual characters of marine sedimentary deposits. The fossils comprise immense numbers of extinct crustaceans, and of brachiopodous mollusca, some marine worms, and many cephalopoda, crinoidea, and corals; a few placoid fishes, are the only vestiges of vertebrated animals; and fucoid plants the sole indications of the vegetable

* Professor Sedgwick on the Structure of the Cumbrian Mountains, Geol. Trans. vol. iv. p. 45-68.

† Professor Sedgwick on the Structure of large Mineral Masses, Geol. Trans. vol. iii. p. 469.

kingdom; not a vestige of any terrestrial animal or plant has been discovered. These organic remains belong for the most part to peculiar types, some of which extend into the upper palæozoic formations, but none occur in the secondary deposits.

In the Cumbrian system, we have a vast argillaceous formation, with numerous conglomerates; and from the structure of the entire series, it would appear that after the deposition of the strata by water, the whole had been exposed to the long-continued influence of heat, by which the original sedimentary character was either greatly modified, or entirely obliterated. As a few fossils occur in the upper part of the system, it will probably hereafter be found convenient to separate the Silurian from the Cumbrian at a lower level than the original base line, and thus include the fossiliferous strata in the former grand division. In accordance with the slaty structure, is the prevalence of igneous rocks throughout the Cumbrian series; for granite, porphyry, serpentine, and trap, occur not only in veins and dikes, but are also intercalated with the strata, as if the melted matter had been poured over argillaceous sediments at the bottom of the sea, and was covered by succeeding deposits.

When dikes of basalt or trap traverse or intersect the limestones or shales, we find them indurated, and sometimes altogether changed in their lithological characters. In the slates, the lines of stratification are more or less manifest, and the rocks have a *cleavage*, that is, a tendency to split in directions which bear no relation to the lines of deposition, as I have already explained (*ante*, p. 798), but have resulted from exposure to a high temperature, by which the character and arrangement of the constituent molecules of the rock have been altered (*Lign.* 182, 183); for a tendency to a similar structure prevails when argillaceous beds are in contact with lava. Where slate rocks have been exposed to a still higher temperature, the transmutation is more complete; as for instance, when granite has been erupted in a state of fusion among schistose strata. The metalliferous veins so abundant in the slate rocks are either intrusions of mineral matter into pre-existing fissures, or sublimations of metallic substances into cavities formed in the rock itself during its refrigeration, and into which the metal was introduced by segregation.

In fine, the Silurian and Cumbrian systems afford proofs of marine depositions going on through immense periods of time in seas inhabited by fishes, crustaceans, crinoideans, corals, and mollusca, belonging to numerous genera and species. For although organic remains prevail only in the uppermost or newest system, yet as we have decided proof that the lowermost has been subjected to intense heat, and that even the lines of stratification are in a great measure melted away, it is reasonable to conclude, that the absence of fossils is attributable to the obliteration of the remains of the animals which lived and died in the waters that deposited these schistose rocks. We must, however, remember, that the relics which remain are of a peculiar type, and altogether different from those of the newer secondary formations.

With the lowest fossiliferous beds of the Silurian and Cumbrian systems, we lose all positive evidence of the presence of organic beings on the surface of the earth; but it would be rash in the extreme therefore, to assume, that these most ancient fossils are the relics of the earliest living things that tenanted our planet. Well has Mr. Lyell remarked, that "it is too common a fallacy to fix the era of the first creation of each tribe of plants or animals, and even of animate beings in general, at the precise point where our present retrospective knowledge happens to stop."*

* Travels in America.

LECTURE VIII.

Part II.—The Volcanic, and Hypogene or Primary Rocks.

1. Introductory. 2. Nature of Volcanic action. 3. Earthquakes. 4. Earthquake of Lisbon. 5. Phlegræan Fields, and the Lipari Isles. 6. Ischia and Vesuvius. 7. Structure of Volcanic mountains. 8. Volcanic products. 9. Lava currents, Dikes, and Veins. 10. Eruptions of Vesuvius. 11. Herculaneum and Pompeii. 12. Conservative effects of Lava streams. 13. Organic remains in Lava. 14. Mount Etna. 15. Val del Bove. 16. Volcano of Kirauea. 17. Mr. Stewart's visit to Kirauea. 18. Volcano of Jorullo. 19. Submarine Volcanoes. 20. Summary of Volcanic phenomena. 21. Hypogene rocks. 22. Mica-schist and Gneiss. 23. Contorted Crystalline rocks. 24. Basalt or Trap. 25. Isle of Staffa. 26. Strata altered from contact with Basalt. 27. Trap dikes in the Isle of Sky. 28. Granite. 29. Granitic eruptions. 30. Metamorphism of rocks. 31. Precious stones. 32. Metalliferous veins. 33. Auriferous alluvia. 34. Cupreous deposits. 35. Transmutation of Metals. 36. Review of the Hypogene rocks. 37. Organic remains in metamorphic rocks. 38. Chronology of Mountain-chains. 39. Systems of elevation. 40. The Great Caledonian Valley. 41. Structure of Ben Nevis. 42. Retrospect. 43. Successive changes in the Organic Kingdoms. 44. Geological effects of Dynamical and chemical action. 45. Strata composed of Organic Remains. 46. General Inferences. 47. The Ancient World. 48. Corollary. 49. Final Effects. 50. Concluding remarks.

1. Introductory.—We have now passed the boundary which separates the animate from the inanimate world, and have entered those regions of geological research in which all traces of organized beings are absent, and various modifications of mineral substances are the only objects that meet our view. The rocks no longer exhibit those organic characters by which we were enabled to decypher the natural records of the past, entombed in the fossiliferous strata; but they are inscribed with hieroglyphics whose

meaning is often obscure and frequently unintelligible, and many of which admit of a double interpretation.

The mechanical effects of water as a fluid, everywhere so manifest in the sedimentary formations, are no longer apparent ; but the powerful agency of the same substance, in the several conditions produced by high temperature—as vapour, steam, and gas,*—is universally exhibited in the upheaved mountain-chains, the protruded igneous matter, the rent and dislocated rocks, and the rugged peaks and precipitous glens, which are the characteristic features of the physical geography of primary regions.

In the phenomena attendant on the earthquakes and volcanoes of modern times, we have proofs of the continued energy of those physical forces which produced the results that will form the principal subjects of this discourse. The nature and effect of volcanic action, to which we have previously, but incidentally, alluded, now, therefore, demand our especial consideration, in order that we may comprehend the origin and formation of the metamorphic and plutonic rocks ; or, in other words, of those mineral masses which have acquired a crystalline structure from exposure to the influence of intense heat under great pressure, and have been elevated into their present position by subterraneous movements. I propose, in the first place, to consider the nature and effects of igneous action as exhibited in existing volcanoes ; secondly, to describe the hypogene and plutonic rocks, and the changes produced in contiguous mineral masses by their influence ; and, lastly, to offer a few general remarks on some of the most important subjects that have engaged our attention.

2. NATURE OF VOLCANIC ACTION.—Volcanic action is defined by Humboldt to be the influence exerted by the

* The beautiful experiments of Mr. Grove prove that water may be reduced to its elementary compounds—oxygen and hydrogen—by intense heat alone. See Philos. Trans. 1846.

internal heat of our planet on its external surface, during its different states of refrigeration and condensation: by which concussions of the land, or earthquakes, and the expansion or elevation, and the subsidence or contraction, of large portions of the solid crust of the earth, have been produced. The number of existing volcanoes is estimated at about 200, of which 116 are situated in America, or its islands.

In the previous discourses, many of the effects of igneous agency came under our notice,* namely, the subsidence and elevation of the Temple of Serapis (p. 106); the gradual rise of Scandinavia (p. 116); the upheaving of the sea-coast of Chili (p. 112); and other mutations of a like nature. As we successively examined the tertiary, secondary, and palæozoic formations, proofs that similar phenomena had taken place during every geological epoch, were equally manifest; the geographical distribution of the foci of volcanic action was found to have varied, but throughout the cycle of physical changes contemplated by Geology, the volcano and the earthquake appear to have been in ceaseless activity. The immediate cause of volcanic action, though not demonstrable, seems to be connected with the fact of a constantly increasing temperature in the interior of the earth, according to the distance from its surface; and which internal heat is probably induced by the excitement of electro-magnetic currents on the mineral matter which composes the mass of our planet. This high temperature of the interior, whatever may be its origin, is the germ not only of earthquakes, which are the purely dynamical effects of volcanic action, but also of the gradual elevation of continents, and of chains of mountains from extended fissures; giving rise to eruptions of lava, mud, boiling water, &c.; to thermal mineral springs,

* A concise view of the effects of high temperature and of volcanic action on the earth's crust, was given in the first Lecture, *ante*, p. 103.

and exhalations of steam, carbonic acid gas, sulphurous vapours, &c. and the production of various rocks and minerals.* In the earlier ages of the globe the phenomena appear to have been of greater extent and in a higher degree of intensity than in modern times.

3. EARTHQUAKES. — The tremblings or vibrations of the solid crust of the globe, denominated Earthquakes, are vertical, horizontal, or gyratory oscillations of the land rapidly succeeding each other; and are caused by the expansive efforts of elastic fluids confined in subterraneous cavities. The craters of volcanoes are the vents through which the imprisoned gases and vapours, and the incandescent mineral matter, force their way to the surface : they are, in fact, the safety-valves of the vast reservoirs of gaseous elements which are contained in the profound depths of the earth. Hence, if the action of a volcano be impeded, earthquakes are commonly induced, and the equilibrium of the land is not restored till the crater resumes its activity, or the imprisoned gases escape through other channels.† A column of smoke which was seen for some months to rise from the volcano of Pasto in South America, suddenly disappeared, when on the 4th of February, 1797, the province of Quito, 192 miles to the southward, was visited by the great earthquake of Riobamba.‡

The focus of volcanic action must be at an immense distance from the earth's surface, though no rational conjecture can be formed either of its depth or of the chemical nature of the compressed fluids : but the vast areas over which the undulations sometimes extend, are proofs of the tremendous power of these subterranean forces.

* Humboldt's Cosmos, p. 181.

† The explosion of a steam-boiler from the closure of the safety valve (as in the recent lamentable catastrophe of the *Cricket* steamboat) is a familiar example of this phenomenon.

‡ Cosmos, p. 203.

4. Earthquake of Lisbon.—The earthquake of Lisbon, in 1775, which suddenly destroyed 60,000 persons, was the most extensively felt of any on record. Its effects were perceived over the whole of Europe, the North of Africa, and in the West Indies: and it is computed that a portion of the earth's surface four times the extent of Europe was simultaneously affected. The enormous undulations of the sea by which it was followed, and that swept along the coasts of Spain, Portugal, and Africa, are supposed to have arisen from the sudden upheaval or subsidence of a vast area of the bed of the Atlantic Ocean, beneath which the principal focus of the subterranean disturbance appeared to be situated. The effects of this earthquake were felt in many parts of England, Scotland, and Ireland, and even as far as Norway; and the waves occasioned by the concussion reached our southern shores, and the waters of Loch Ness, and of other inland lakes, were simultaneously agitated. Even the thermal springs of countries remote from the catastrophe were affected: those at Toplitz in Bohemia, which for centuries had flowed in a pure and equal stream, suddenly ceased, and then burst forth in a flood of turbid water of a very high temperature.

Humboldt remarks, that it is probable the earth's surface is always disturbed at some one point, and that it is incessantly affected by the reaction of the interior against the exterior. The permanent elevation of extensive tracts by earthquakes sometimes takes place; as on the coast of Chili, in 1822 (*ante*, p. 112); and they are often accompanied with eruptions of mud, steam, hot water, carbonic acid gas, and other elastic fluids.

The present grand European centre of volcanic action is in Southern Italy, which has for ages been in a state of energy; Etna, Vesuvius, and the Lipari Isles, being the vents through which the incandescent materials have escaped.

5. THE PHLEGRÆAN FIELDS AND LIPARI ISLES.—The volcanic region of Naples consists of a linear group of cones, ranging N.E. and S.W., and terminating at either extremity by the two principal mountains, Ischia and Vesuvius; the latter seems to be connected by the intervention of minor vents with the group of Albano and of Rome; the seven hills of the Eternal City being volcanic mounds.*

The district of Puzzuoli and Cumæ, on the Bays of Baiæ and Naples, is called the Phlegræan Fields, and in it are situated Monte Nuovo, Monte Barbaro, the Solfatara, and the Temple of Serapis. This tract presents a series of cones and crateriform basins; some of which contain lakes, as those of Avernus and the Lucrine. These volcanic mounds are formed of felspathic tufa, occasionally containing marine shells and carbonized wood, and are covered by beds of loose tufaceous conglomerate. They are supposed by Mr. Scrope to have been produced by numerous submarine eruptions, each from a fresh focus, on a shallow shore.†

The volcanic cone termed the SOLFATARA, so well known from its incessant emission of torrents of aqueous and sulphurous vapour, through superficial fissures, is recorded as having been in a state of activity in the year A.D. 1180. Mr. Scrope supposes the present crater to have been formed at that period; and he attributes the constant emanations of sulphuretted hydrogen, to the effect of a mass of lava still existing beneath at an intense temperature. The chemical changes effected by the immediate conversion of this gas into sulphuric acid, from combination with the oxygen of the atmosphere, and the subsequent action of the acid on the tufas, trachytes, &c., giving rise to sulphates of alumine, iron, lime, magnesia, soda, &c.; while the silex is left nearly

* Mr. Scrope, Geol. Trans. vol. ii. p. 337.
† Scrope on Volcanoes, p. 179.

pure, in the state of a white earthy powder, are in the highest degree interesting.*

The earthquakes of 1538, which were followed by an eruption of mud, pumice-stone, and ashes, that burst forth from a gulf near the town of Tripergola and formed the volcanic mound called Monte Nuovo, and by the permanent elevation of the coast to beyond Puzzuoli, were mentioned in a former Lecture (*ante*, p. 109).†

The Lipari Isles, between Naples and Sicily, lying, as it were, midway between Vesuvius and Etna, present a character very analogous to the district above described. The crater of one of the islands, Stromboli, has been in constant activity from the earliest historical period. It always contains melted lava in constant motion, and at uncertain intervals the molten mass suddenly rises, and large bubbles appear, which, upon reaching to the brim of the crater, explode with a sound resembling thunder, and masses of lava, with dust and smoke, are thrown into the air ; the incandescent fluid then sinks down to its former level.‡

The Cliffs of St. Calogero, which are about two hundred feet high, and extend four or five miles along the coast, consist of horizontal beds of volcanic tuff. From the perennial emanation of sulphurous vapours, the rocks are decomposed ; alum, gypsum, and other sulphuric salts, are formed, as well as muriate of ammonia, and silky crystals of boracic acid. The dark clays have become yellow, white, red, pink, &c. and marked with stripes of various colours, from the gaseous emanations that are constantly issuing from beneath : these mottled clays strikingly resemble in appear-

* Geol. Trans. vol. ii. p. 345. See also, *ante*, p. 77, and Sir H. Davy's remarks on the Lake of the Solfatara, in the Appendix to vol. i. p. 452.

† A letter on the formation of Monte Nuovo, by an eye-witness, is still extant : a translation of it, by Mr. Leonard Horner, is published in the Quarterly Journal of the Geological Society of London, No. 9, p. 19.

‡ Spallanzani.

ance the variegated strata of the Trias (*ante*, p. 543). Veins of chalcedony and opal occur, and pumice-stone and obsidian are abundant. Dikes and veins of trachyte intersect the tuff in every direction (*Lign.* 184, *fig.* 1), like the intrusions of trap in the ancient sedimentary formations.

6. ISCHIA AND VESUVIUS.—The celebrated mountain of Vesuvius, or Somma, is about four thousand feet high, and its crest is now broken and irregular; but when northern Italy was first colonized by the Greeks, "its cone was of a regular form, with a flattish summit, where the remains of an ancient crater, nearly filled up, had left a slight depression, covered in its interior by wild vines, and with a sterile plain at the bottom." From the earliest period to which tradition refers, to the first century of the christian era, this mountain was in a dormant state, and the neighbouring isles of Ischia and Procida were the theatres of constant explosions and earthquakes. The early Greek colonists who attempted a settlement, were obliged to abandon the territory, in consequence of the frequency and violence of the subterranean movements.

Ischia.—But subsequently to the great outburst of Vesuvius, Ischia has been almost entirely dormant; and it is therefore inferred that the latter volcano was the vent through which the elastic fluids and incandescent materials of the subterranean fires of Italy escaped, before Vesuvius resumed its activity. Ischia has numerous cones; the central one, Epomeo, is 2,600 feet high, and has traces of two large craters on its summit. This mountain appears to have been submarine at its origin, but, since its elevation above the sea, other eruptions have burst out at various points; and a lava-stream that issued from its base is still arid, and covered in parts with cinders and scoriæ. The materials erupted by the cones of Ischia are, for the most part, trachytes, or felspathic lavas.

Vesuvius.—In the year 63 of the christian era, Vesuvius exhibited the first symptom of internal change, in an earthquake which occasioned considerable damage to many neighbouring cities, and of whose effects traces may yet be witnessed among the interesting memorials of the awful catastrophe which soon afterwards took place.* After this event, slight shocks of earthquakes were frequent, when on the 24th of August, in the year 79, a tremendous eruption of the long pent-up incandescent materials of the volcano burst forth, and spread destruction over the surrounding country, overwhelming three cities, with many of their inhabitants, and burying all traces of their existence beneath immense accumulations of ashes, sand, and scoriæ. All the fearful circumstances connected with this event, and the attendant physical phenomena, are so well known, that it is unnecessary to dwell upon the subject.

From that period to the present time, the internal fires of Italy have resumed their ancient focus, and Vesuvius, with occasional periods of tranquillity, has been more or less energetic.

7. Structure of Volcanic Mountains. — As the present active volcanoes for the most part emit streams of lava, showers of ashes, cinders, and scoriæ, and floods of mud or tuff, their cones consist of erupted materials disposed more or less concentrically; and where sections are exposed, the beds have what is called a *qua-qua-versal* dip; that is, they regularly incline on every side of the mountain. These are termed *Craters of Eruption;* they consist of successive strata of volcanic matter poured out from a fissure or vent, communicating with the deep-seated focus of igneous action.

The central crater of another class of volcanic mountains, is formed of pre-existing horizontal rocks and strata, that have been forced into highly inclined positions by a sudden and violent upburst of incandescent mineral matter,

* Daubeny on Volcanoes, p. 152. Scrope on Volcanoes.

or by the expansion of elastic vapours. A dome or cone is thus produced, with a central opening, around which the uplifted strata are concentrically arranged; being covered to a greater or less extent by the materials poured out by subsequent eruptions. These are termed by M. Von Buch, *Craters of Elevation*. The structure of such volcanic mountains will be readily understood by referring to the sections of the Wren's Nest (*ante*, p. 771), and of Crich Hill, near Matlock (*ante*, p. 685), both of which are examples of originally horizontal strata elevated into a dome by a protrusion of volcanic matter. If in either of these instances the upheaving force had been sufficient to propel the trap through the middle of the dome, a crater of elevation would have been formed, through which the igneous matter would have escaped. It is by a movement of this kind, as we have already had occasion to explain, that valleys of elevation have been produced (*ante*, p. 779).

Mr. Scrope's observations on the structure of Vesuvius will serve to explain the formation of craters of eruption:—

"Vesuvius is an exceedingly regular mountain on a small scale. All the visible lavas, and the greater part of the conglomerates, are basaltic; and, owing to the great fluidity of lavas of this mineral character, they have, when produced from the common vent, taken their course in spreading sheets down the outer slope of the mountain; while the scoriæ and fragmentary substances, projected at the same time into the air, were spread pretty evenly over them; so that the result of successive eruptions of this kind, has been the formation of a regularly conical mountain, with a gradually diminishing slope on all sides, from the central heights to the plain around; exhibiting in the ravines that furrow its sides, as well as in the abrupt sections afforded by the walls of the great crater, its composition of repeatedly alternating beds of basalt and basaltic conglomerates, more or less irregular in thickness, but dipping uniformly on all sides away from the vent, with an inclination corresponding exactly to the external slopes of the mountain.

"The eruptions of Vesuvius seem very rarely to have taken place from any other than the central vent; a few small cones immediately above Torre del Greco, thrown up in 1794, and the cone on which the Camaldoli della Torre is built, are the only indications of explosions having burst from the sides of the mountain. The vast number of vertical basaltic dikes which intersect the horizontal beds observable in the broken cliffs of the old crater (Atrio del Cavallo) bear witness, however, that the lava was not so frequently elevated to the summit of the mountain, without occasioning numberless cracks and rents in its internal structure. There is great reason to conclude that the old crater of Somma, whose steep walls now half encircle the cone of Vesuvius, was formed by the celebrated eruption of the year 79, which occasioned the death of the elder Pliny, and buried Herculaneum, Pompeii, and Stabiæ, beneath a bed of ashes and fragmentary scoriæ, &c. from thirty to one hundred feet in thickness."*

8. Volcanic Products.—Before we pass to the consideration of the phenomena attendant on a volcanic eruption, we will examine some of the principal minerals which enter into the composition of the lavas and other substances ejected from volcanoes.

Lava is a term applied to any mineral matter liquefied by heat, that has issued in a stream or current from a volcanic aperture: when consolidated by cooling, it may consist either of scoriæ, pumice, basalt, trachyte, obsidian, &c. according to its mineral composition, and its slow or rapid refrigeration. The greater or less degree of pressure under which the solidification either of liquid or merely softened mineral substances takes place—as, for example, in the open air, or at the bottom of the sea, or in deep-seated subterranean cavities—appears to be the principal cause of the difference between the ancient plutonic, and the volcanic rocks.†

Among the products of modern volcanoes, five of the metals occur; namely, iron, copper, lead, arsenic, and selenium. The number of simple minerals found in the rocks of Vesuvius amounts to 400 species; and many of them are of great beauty. Specular iron is common in the cavities

* From the Memoir on the Volcanic District of Naples, by Poulett Scrope, Esq., Geol. Trans. vol. ii. p. 337.

† Humboldt.

of the hard lavas. In some of the ancient Vesuvian lavas there are decided indications of a concretional and prismatic structure, and a tendency to divide into columns, like the basaltic rocks.

Aqueous vapours are emitted in abundance from volcanoes, and often from their condensation give rise to copious springs. The gaseous emanations from the fumaroles, or lesser vents, frequently contain chlorides of lead, iron, copper, ammonia, soda, &c.

The lofty volcanic peaks which reach far above the limits of perpetual snow, as those of the Andes, (*Cotopaxi*, which is 19,070 feet high,) are frequently the cause of frightful inundations from the sudden melting of the snow, occasioned by the evolution of heat during an eruption. Torrents of water, bearing along heated masses of scoriæ and blocks of ice, rush down the sides of the mountains, and overwhelm the plains below. Water from the melted snow is also continually finding its way into the hollows and fissures of the trachytic rocks, and vast subterranean lakes are thus formed in the interior of the volcanic mass: and when these reservoirs are burst open by the earthquakes that precede eruptions, water, and tufaceous mud, not unfrequently accompanied with swarms of fishes that inhabited the internal pools, are ejected with great violence.

The chief constituents of lavas are the substances termed *felspar* and *augite*, and *titaniferous iron*, and the lavas are classed according as either of these ingredients predominates. When the felspar prevails, the mass is called *Trachyte*, which is generally of a coarse grain, with a harshness of texture, and a degree of porosity; when the grain is fine and compact, but irregular, it constitutes *Trachytic Porphyry;* when the particles are so fused as to have a resinous or glassy texture, it forms *Pitchstone* and *Obsidian.* If *Augite* or *titaniferous iron* constitute a large proportion of a rock, it is termed *Basalt;* and when the structure is slaty, *Clinkstone.* The same substance forms augite when it cools rapidly, and *hornblende* when the refrigeration takes place slowly.

The lavas ejected from Vesuvius present considerable variety of appearance and composition: they occur in the state of pumice-stone; vesicular scoriæ, that is, cinders full of hollow cells; and compact heavy masses of molten rock, which are sometimes spotted internally with red, yellow, and grey. Mica occurs plentifully in some recent trachytes, but crystallized quartz and hornblende, so abundant in granite, are extremely rare. Pumice is supposed to be produced by a considerable disengagement of vapour having taken place while the lava was in a plastic, but not entirely in a fluid state; the escape of the gaseous matter giving rise to the porous structure of this mineral. Dolomieu observes, that one kind of pumice seems to be derived from the fusion of granite, since it contains fragments of quartz, mica, and felspar, and that when such fragments were exposed to heat they were converted into a substance resembling the surrounding pumice.

9. Lava currents, dikes, and veins.—As the aspect and nature of lava currents will be easily comprehended, by the descriptions of volcanic eruptions which I shall presently place before you, it will suffice to mention in this place, that the appearance of lava in motion is that of a sluggish viscid stream loaded with red-hot cinders and ashes, and detached fragments of rocks, rolling one over the other, and producing a loud crackling noise. Captain Basil Hall aptly compares the movements of a lava-current to that of a glacier;—" They are both," he observes, " more or less, frozen or half-congealed rivers; they both obey the law of gravitation with great reluctance, being essentially so sluggish, that although they move along the bottoms of valleys with a force well-nigh irresistible, yet their motion is sometimes scarcely perceptible. Both glaciers

and lava-streams, by occasionally acting the part of huge dams across valleys and ravines, cause immense accumulations of water; it is true these barriers are more fragile in the case of glaciers, and the consequences are therefore the more destructive."*

The effects produced by lava-currents, and their rate of progress, depend of course on their degree of incandescence and fluidity. When the molten mass first issues, it appears like a stream of fire, but the surface quickly acquires a rough scum, or crust, which soon thickens, and is broken into angular pieces by the onward motion of the fluid beneath. In this condition it appears like melted iron or copper, and if a stick be thrust in, large semifluid masses adhere, and may be removed; and coins or other articles may be plunged in, and will remain permanently imbedded when the lava cools.†

Lava-currents from Vesuvius have flowed a mile and a half in fourteen minutes; others have reached the sea in three hours from the summit of the mountain, a distance of 3,200 yards. The stream which destroyed Catania in 1669, was fourteen miles long and five wide. In Etna, currents have been traced forty miles in length; and a stream that issued from Mount Hecla, in Iceland, is computed at ninety-four miles in length, and fifty in its greatest breadth; and its depth, where there were obstacles to its progress, was in some places several hundred feet.

Lava currents retain a high temperature for a long period; some have been observed to flow slowly ten years after their eruption. A mass of lava on the flanks of Vesuvius ignited wood thrust into it four years after its motion had ceased.

The cooled lavas, and other mineral products which form

* Patchwork, by Captain Basil Hall, vol. iii. p. 153.

† Persons visiting Vesuvius generally bring away such mementos of their ascent to its crater.

the great mass of a volcanic mountain, are rent and torn by the earthquakes, which generally precede every fresh eruption; and these fissures and chasms become filled by subsequent injections of molten rock. In this manner dikes and veins are formed in the trachytic and scoriaceous masses of Vesuvius, Etna, and other active volcanoes (*Lign.* 184), resembling, on a small scale, the intrusive trap-dikes in the ancient strata, of which we have already noticed many examples.

1

2

LIGN. 184.—DIKES AND VEINS IN LAVA.

Fig. 1. Veins and dikes of slaggy lava in volcanic tuff; Stromboli.
—— 2. Lava dikes in scoriæ and sand; Etna.

The loose sand, scoriæ, and ashes, which have been either wafted by the winds and fallen into the sea, or washed down by torrents on the plains, become agglutinated together, and form an earthy conglomerate, which is termed volcanic *tuff*. This substance is frequently traversed by veins and dikes of lava, thrown up by subsequent eruptions. It often happens that the beds thus permeated, being formed of materials that readily decompose, are partially or wholly worn away, while the durable intruded dikes remain, and stand out in relief, sometimes forming vertical walls or buttresses, of great thickness and extent; of which the celebrated Val del Bove, of Etna, to be noticed in the sequel, affords the most remarkable examples.

10. ERUPTIONS OF VESUVIUS.—In the early periods of activity, violent gaseous explosions, with showers of scoriæ, ashes, and sand, characterized the eruptions of Vesuvius;* but since the existence of the present crater, lava-currents have generally been ejected. The appearance of an ordinary eruption, seen by night, is thus graphically described by a late traveller:—

"It was about half-past ten when we reached the foot of the craters, which were both tremendously agitated; the great vent threw up immense columns of fire, mingled with the blackest smoke and sand. Each explosion was preceded by a bellowing noise like thunder in the interior of the mountain. The smaller vent was the most active; and the explosions followed each other so rapidly that we could not count three seconds between them. The stones which were emitted were fourteen seconds in falling back to the crater; consequently, there were always the discharge of five or six explosions—sometimes more than *twenty*—in the air at once. These stones were thrown up perpendicularly, in the shape of a wide-spreading sheaf, producing the most magnificent effect imaginable. The smallest stones appeared to be of the size of cannon-balls; the greater were like bomb-shells; but others were pieces of rock, five or six cubic feet in size, and some of most enormous dimensions: the latter generally fell on the ridge of the crater, and rolled down its sides, splitting into fragments as they struck against the hard and cutting masses of cold lava. The smoke emitted by the smaller cone was white, and its appearance inconceivably grand and beautiful; but the other crater, though less active, was much more terrible; and the thick blackness of its gigantic volumes of smoke partly concealed the fire which it vomited. Both vents occasionally burst forth at the same instant, and

* The craters of Auvergne, (*ante*, p. 268,) that exhibit no traces of lava currents, are also supposed to have been produced by explosions.

with the most tremendous fury, the ejected stones intermingling in the air.

"If any person could accurately fancy the effect of 500,000 sky-rockets darting up at once to a height of three or four thousand feet, and then falling back in the shape of red-hot balls, shells, and large rocks of fire, he might have an idea of a single explosion of this burning mountain; but it is doubtful whether any imagination can conceive the effect of one hundred of such explosions in the space of five minutes, or of twelve hundred or more in the course of an hour, as we saw them! Yet this was only a part of the sublime spectacle before us.

"On emerging from the darkness, occasioned by the smaller crater being hidden by the large one, as we passed round to the other side of the mountain, we found the whole scene illuminated by the river of lava, which gushed out of the valley formed by the craters and the hill on which we now stood. The fiery current was narrow at its source, apparently not more than a few feet in breadth; but it quickly widened, and soon divided into two streams, one of which was at least forty feet wide, and the other somewhat less: between them was a sort of island, below which they reunited into one broad river, that was at length lost sight of in the deep windings and ravines of the mountain."*

The streams of lava issue with great velocity, and are in a state of perfect fusion; but as they cool on the surface, they crack, and the matter becomes vesicular, or porous; at a considerable distance from their source, they resemble a heap of scoriæ, or cinders, from an iron-foundry, rolling slowly along, and falling, with a rattling noise, one over the other.

In an eruption witnessed by Sir W. Hamilton, jets of liquid lava, mingled with stones and scoriæ, were thrown up to a height of ten thousand feet.

* From the Saturday Magazine.

11. Herculaneum and Pompeii.—Such are the phenomena attendant on the modern paroxysms of Vesuvius: but this celebrated mountain is invested with surpassing interest, from the wonderful preservation of the cities which were overwhelmed by its first recorded eruption, in the seventy-ninth year of the Christian era.

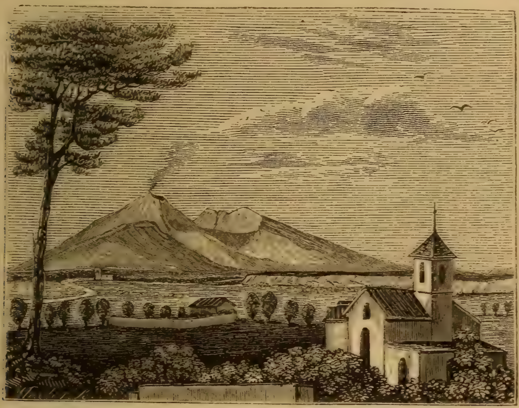
In the words of an eloquent writer, "After nearly seventeen centuries had rolled away, the city of Pompeii was disinterred from its silent tomb—all vivid with undimmed hues,—its walls fresh as if painted yesterday,—not a tint faded on the rich mosaic of its floors,—in its Forum the half-finished columns, as left by the workman's hand,—before the trees in its gardens the sacrificial tripod,—in its halls the chest of treasure,—in its baths the strigil,—in its theatres the counter of admission,—in its saloons the furniture and the lamp,—in its triclinia the fragments of the last feast,—in its cubicula the perfumes and the rouge of faded beauty,—and everywhere, the skeletons of those who once moved the springs of that minute, yet gorgeous machine of luxury and of life."*

From the description of this catastrophe by an eye-witness, it appears that this outburst of Vesuvius was marked by a terrific eruption of ashes and scoriæ, which, borne upwards by vapours, rose in an immense column, and is described by the younger Pliny, in his letter to Tacitus, as resembling a lofty pine spreading out at its summit into wide shadowing branches:† and then followed total darkness, occasioned

* Sir E. Bulwer Lytton's Last Days of Pompeii.

† The elder Pliny, who, at the time of this outburst of Vesuvius, held the command of the Roman fleet, stationed at Misenum—a Cape or headland about twice the distance westward from the volcano, as the city of Naples—in his anxiety to obtain a nearer view of the phenomenon, fell a victim to the sulphurous vapours: and his nephew, the younger Pliny, who remained with the fleet at Misenum, has left a graphic description of the awful scene in his letters to Tacitus. He states, that a dense column of vapour was first seen arising verti-

by the descent of this overwhelming cloud of volcanic matter, which completed the destruction of the devoted cities, and buried Herculaneum, Pompeii, and Stabiæ,



LIGN. 185.—VIEW OF VESUVIUS, LOOKING OVER THE PLAIN AND CITY OF POMPEII.

The site of *Pompeii* is marked by the long line of embankments in the middle distance, formed by the ashes thrown out of the excavations. The river *Sarnus* is seen on the left.

(From Sir W. Gell's Pompeiana.)

beneath an accumulation of ashes, cinders, and scoriæ, to a depth of from sixty to one hundred and twenty feet.

No traces have been perceived of lava currents or of

cally from Vesuvius, and which spread itself out laterally, so as to resemble the head and trunk of the Italian pine-tree. This black cloud was occasionally pierced by flashes of fire as vivid as lightning, and the whole atmosphere suddenly became darker than night. The eruption burst forth with such amazing force, that ashes fell even upon the ships at Misenum, and in such quantities as to cause a shoal in one part of the neighbouring sea. In the meantime, the ground rocked terribly; and the sea receded so far from the shore, that many marine animals were left exposed on the dry sand.

melted matter; the various utensils and works of art, as you may observe in the lamps, vases, beads, and instruments in the British Museum, exhibit no appearance of having been exposed to the action of fire. Even the delicate papyri appear to have sustained more injury from the effects of moisture and exposure to the air, than from heat; for they contain matter soluble in naphtha, and are in fact peat in which bituminization has commenced.* In Pompeii, the sand and stones are loose and unconsolidated; but in Herculaneum, the houses and works of art are imbedded in solid tuff, which must have originated either from a torrent of mud, or from ashes moistened by water. Hence statues are found unchanged, although surrounded by hard tuff, bearing the impressions of the minutest lines. The beams of the houses have undergone but little alteration, except that they are invested with a black crust. Linen and fishing-nets, loaves of bread with the impress of the baker's name; even fruits, as walnuts, almonds, and chestnuts, are still distinctly recognizable. The remarkable preservation, for nearly two thousand years, of whole cities, with their houses, furniture, and the most perishable substances, imbedded in volcanic matter, may be compared to those geological events, by which the forests of an earlier world, and the remains of the colossal dragon-forms which inhabited the ancient lands and waters, have been accumulated beneath the deposits of innumerable ages.

12. CONSERVATIVE EFFECTS OF LAVA CURRENTS.—Although no vestiges of animals or plants are likely to be found in volcanic products that have been in an incandescent state, yet so slow is the conducting power of many earths, that beds of shells, and vegetable remains, may be overflowed by streams of molten lava without injury, if protected by even a thin covering of sand or other non-conducting material. In like manner the ancient basaltic lavas have

* Dr. Macculloch.

burst through and overwhelmed sedimentary strata, and yet the most delicate animal and vegetable substances remain uninjured; transmuted, indeed, into stone, but still retaining their original structure. Thus, in the cretaceous beds of Glaris, although the rock has been converted into slate by intense heat, yet the fishes remain (*ante*, p. 353); the strata of Monte Bolca, though capped with basalt, yet swarm with ichthyolites (p. 265); the fiery currents of Auvergne have flowed over the lacustrine limestones, and still vestiges of insects, serpents, and quadrupeds, are preserved (p. 274); the tertiary forests of the Andes, which grew on beds of lava, now lie buried beneath subsequent volcanic eruptions of prodigious thickness (p. 284); and bones either of the Dodo, or of the Solitaire, are found imbedded in sandstone, covered by lava of recent origin (p. 132).

A very remarkable circumstance is mentioned by Mr. Lyell,—the preservation of a bed of ice, beneath a stream of incandescent lava. The intense heat experienced in the south of Europe, during the summer and autumn of 1828, caused the usual supplies of ice entirely to fail. Great distress was consequently felt from the want of a commodity, regarded in those countries rather as an article of necessity than of luxury. Etna was, therefore, carefully explored, in the hope of discovering some crevice, or natural grotto on the mountain, where drift snow was still preserved. Nor was the search unsuccessful; for a small mass of perennial ice, at the foot of the highest cone, was found to be part of a large, continuous glacier, covered by a sheet of lava. The ice was quarried, and the superposition of the lava ascertained to continue for several hundred yards; unfortunately, the ice was so extremely hard, and the removal of it so expensive, that there is no probability of the operations being renewed.* Mr. Lyell explains this apparently para-

* Principles of Geology, vol. ii. pp. 124—126.

doxical fact, by supposing that a deep mass of drift snow was covered by a stream of volcanic sand, which is an extremely bad conductor of heat; and thus the subsequent liquid lava might have flowed over the whole, without affecting the ice beneath, which at such a height (ten thousand feet above the level of the sea) would endure as long as the snows of Mont Blanc, unless melted by volcanic heat from below.

13. ORGANIC REMAINS IN LAVA.—The siliceous shields, or cases of Infusoria, are often found as a component part of volcanic ash and tuff, both of ancient and modern origin, and were probably derived from the subterranean pools or lakes; as in the case of the showers of fishes which occasionally descend during a volcanic eruption.* Infusorial shields are not uncommon in the volcanic dust that falls on vessels, often hundreds of miles from land. An ancient bed of tuff in Oregon is full of infusorial remains.†

In the tuff of Vesuvius, I have seen the impressions of dicotyledonous leaves; and charred wood is occasionally met with in the scoriæ of Herculaneum.

A curious circumstance occasionally results from the invasion of a grove or forest by a stream of lava. The trunks of the trees, at their base, become enveloped by the molten mass, but the upper part and the branches are set on fire, and burn down to the surface. The trunks surrounded by the lava are only charred, and if, as often happens, this carbonaceous matter is washed away, or otherwise removed, hollow cylindrical tubes, having their sides marked with the imprint of the bark of the trunks, remain in the solid rock. Such moulds are not uncommon in the Isle of Bourbon, in those lava currents that have extended their ravages through the palm-forests.

* Humboldt's Cosmos, p. 222. A putrid fever prevailed in 1691, in Ibarra, north of Quito, from the quantity of dead fish ejected from the volcano of Imbaburu.

† Dr. Bailey.

A remarkable fact, arising from a similar cause, is mentioned by Count Strzelecki, as having come under his notice in the valley of the Derwent in Van Diemen's Land. Opalized coniferous wood is abundant, and in some parts the truncated stumps are imbedded in porous and scoriaceous basalt, and trachytic conglomerate, and in many instances the basalt contains hollows, which are the moulds of trees that have been consumed. It appears that the stems which had been silicified withstood the intensity of the incandescent lava; while other trees, placed in circumstances unfavourable to their previous petrifaction, were charred, but not destroyed; and from their having been either green, or saturated with water, they resisted the progress of combustion, so as to leave cylindrical upright cavities in the basaltic scoriæ, with impressions similar to the rugged bark of a carbonized tree. Into some of these hollows a second eruption of lava has formed casts of the consumed trunks in basalt.*

14. Mount Etna.—This volcanic cone, which is situated in the island of Sicily, and is entirely composed of erupted mineral substances, rises majestically to the height of upwards of two miles (or 10,872 feet), the circumference of its base exceeding 180 miles; on a clear day it may be distinctly seen from Malta, a distance of 150 miles. Compared with this prodigious mass of igneous products, Vesuvius sinks into insignificance; for while the lava streams of the latter do not exceed seven miles, those of Etna are often from fifteen to thirty miles in length, and five miles in breadth, and from fifty to one hundred feet in thickness.† The surface of Etna presents three distinct regions: around the base for an extent of twelve miles, the country is richly cultivated, and abounds in vineyards and pastures, and is the site of many towns, monasteries, and villages. The

* Physical Description of New South Wales.

† Dr. Daubeny on Volcanoes.

middle, or temperate zone above, is covered with forests of oak and chestnut, and a luxuriant vegetation reaches to within a mile of the summit. Above this all is sterility and desolation, and the highest point of the mountain is covered with eternal snow. The crater is about a quarter of a mile in height, and three quarters of a mile in circumference, and is situated in the centre of a gently inclined plain, three miles in diameter. From the crater a column of vapour constantly issues, emanating from the mass of incandescent mineral matter which fills up the interior, and may be seen, in a state of ebullition, in the fumaroles or chasms in some of the lateral crevices, of which there are generally several accessible.

Etna is recorded as having been in a state of activity before the Trojan war; and ever since, at varying intervals, violent eruptions have occurred. In an eruption in 1669, the torrent of lava inundated a space of fourteen miles in length, and four in breadth; burying beneath it 5,000 villas and other habitations, with part of the city of Catania, and at length falling into the sea: during several months before the lava burst out, the old mouth, or great crater, was observed to send forth more smoke and flame than usual, and the top fell in; so that the cone became much lowered.

In 1809, twelve new craters opened, about half way down the mountain, and threw out rivers of burning lava, by which several estates and farms were covered to the depth of thirty or forty feet: and in 1811, other vents appeared on the eastern side, and discharged torrents of liquid lava with amazing force.

In 1832, a violent paroxysm took place, and continued with but little intermission for several weeks. "On the 31st of October, in the middle of the night, there arose, without any previous indication, a column of smoke and flame from the base of the large cone, on the northern side; and, shortly after, an immense quantity of fluid matter was discharged from the crater, on the western side, divided into numerous streams. Next morning, repeated earthquakes, the increased noise of the lava, which now flowed rapidly, and the immense volumes of thick black smoke at the foot of Monte Scavo, announced that the eruption had greatly increased in violence, and several streams of lava were seen descending. On the 2d of November, contrary to all expectation, the eruption ceased, and the lava was found to be so far cooled, that several adventurous observers were enabled to get upon it, and walk a few paces. On the 3d, the hope that the fire was almost extinct was nearly certain; but, in the evening, a violent earthquake, followed by several smaller ones, with a fresh quantity of smoke, foretold a fresh eruption; and two hours before midnight, another severe shock occurred, and was succeeded by black smoke mingled with flames, and incessant thunder.

"Having approached," says Signor di Luca, "as nearly as was prudent, to the hollow from which the fire issued, we found four apertures, which threw out burning matter. Raising our eyes from these vents, we observed a cleft or rent, about a mile in length, from which volumes of smoke arose from time to time; and, as at the bottom it reached the openings above mentioned, it enabled us to behold the burning furnace in the interior of the mountain. Meanwhile, the thunder was incessant, and the detonations were terrible; the lava continued to flow; and enormous masses of red-hot substances were thrown to a great height, mingled with vast volumes of flame and smoke. The shocks of earthquake were likewise so violent, that horses, and other animals, fled in terror from the places where they were feeding."

15. THE VAL DEL BOVE.—But by far the most interesting feature of Etna is an immense depression or excavation on the eastern side of the mountain, called the *Val del Bove.* This vast plain or rather circular hollow, is five

miles in diameter, and from two to three thousand feet in the height of its bounding precipices, which in most places are nearly perpendicular. This remarkable area appears to have resulted from the giving way and subsidence of part of the crust of the volcano, from some violent action in the interior, which occasioned the sudden removal of an enormous mass of mineral matter.* This plain is encircled by subordinate volcanic mountains, some of which are covered by forests, while others are bare and arid like many of the cones of Auvergne. The walls or cliffs surrounding this depression, are formed of successive layers of lava of variable thickness, with interposed beds of tuff, ashes, and igneous conglomerates of different colours and degrees of fineness. They slope downwards towards the sea at an angle of from twenty to thirty degrees, and have evidently been formed at various intervals by successive eruptions from the top of the mountain, and were continuous before the subsidence took place which gave this region its present character.

The perpendicular sides of this natural amphitheatre are everywhere marked by vertical walls or dikes, which not only intersect the concentric sheets of lava and tuff, but standing out in bold relief, like prodigious buttresses, impart a most extraordinary character to the scene; the greater induration of these intruded dikes having enabled them to resist the denuding action which

* Sudden depressions of the surface of the land, are not unfrequent concomitants of subterranean movements, and occasionally produce the most frightful catastrophes. In 1772, Papandayang, one of the largest volcanoes in the Island of Java, suddenly sunk down, with a terrific noise, and an area fifteen miles long and six wide was swallowed up; many hundred persons and forty villages were destroyed: being either engulfed with the sunken mass, or overwhelmed by the volcanic matter that issued forth, and spread over the surrounding country to a considerable distance. The original mountain was diminished 4,000 feet in height.

has removed the less coherent pre-existing erupted materials.* These buttresses are from two to twenty feet in thickness, and being of immense height, are extremely picturesque ; some of them are composed of trachyte, and others of blue compact basalt with olivine. The surface of the plain is wild and desolate in the extreme, presenting the appearance of a tempestuous sea of liquid lava, suddenly congealed. Innumerable currents of lava are seen piled one upon the other ; some of which terminate abruptly, while others have extended across the Val, and descended in cascades into the lower fertile regions, where they are spread out in sterile tracts amid the vineyards and orange-groves.†

The varied and picturesque scenery of Etna, the phenomena of volcanic action which are there so strikingly exhibited, as well as those which have taken place in periods long antecedent to human history and tradition, but of which the natural records remain, are described by Mr. Lyell with that vigour and fidelity which characterize all the productions of his pen ; and his works should be consulted by those who desire fully to comprehend the nature of some of the most interesting physical changes which are in progress on the surface of our planet.‡

16. VOLCANO OF KIRAUEA.—Of the existing volcanoes that of Kirauea, in Hawaii,§ exhibits volcanic action in its most sublime and imposing aspect. The island of Hawaii, which is about seventy miles long, and covers an area of 4,000 square miles, is a complete mass of volcanic matter,

* See *ante*, p. 819.

† See Captain Basil Hall's graphic description of a visit to the Val del Bove, Patchwork, vol. iii. p. 31.

‡ See Principles of Geology, vol. ii. p. 415. Elements of Geology, vol. ii.

§ Hawaii is one of the Sandwich Islands, and is well known under its former name of Owhyhee, as the scene of the murder of Captain Cook.

perforated by innumerable craters. It is in fact a hollow cone, rising to an altitude of 16,000 feet, having numerous vents over a vast incandescent mass, which doubtless extends beneath the bed of the ocean; the island forming a pyramidal funnel from the furnace beneath, to the atmosphere. The following graphic account of a visit to the crater by Mr. Ellis, affords a striking picture of the splendid, but awful spectacle, which this volcano presents.

"After travelling over extensive plains, and climbing rugged steeps, all bearing testimony of igneous origin, the crater of Kirauea suddenly burst upon our view. We found ourselves on the edge of

Lign. 186.—The Volcano of Kirauea, in Hawaii.

(From Ellis's Polynesian Researches.)

a steep precipice, with a vast plain before us, fifteen or sixteen miles in circumference, and sunk from two hundred to four hundred feet below its original level. The surface of this plain was uneven, and strewed over with large stones and volcanic rocks; and in the centre of it was the great crater, at the distance of a mile and a half from the precipice on which we were standing. We proceeded to the northern end of the ridge, where, the sides being less steep, a descent to the plain below seemed practicable; but it required the greatest caution, as the stones and fragments of rock frequently gave way under our feet, and rolled down from above. The steep which we had descended was formed of volcanic matter, apparently of light red and grey vesicular lava, lying in horizontal beds, varying in thickness from one to forty feet. In a few places the different masses were rent in perpendicular and oblique directions, from top to bottom, either by earthquakes, or by other violent convulsions of the ground. After walking some distance over the plain, which in several places sounded hollow beneath our feet, we came to the edge of the great crater. Before us yawned an immense gulf in the form of a crescent, about two miles in length from north-east to south-west, one mile in width, and 800 feet deep. The bottom was covered with lava, and the south-west and northern parts were one vast flood of burning matter. Fifty-one conical islands of varied form and size, containing as many craters, rose either round the edge or from the surface of the burning lake. Twenty-two constantly emitted either columns of grey smoke, or pyramids of brilliant flame: and at the same time vomited from their ignited mouths streams of lava, which rolled in blazing torrents down their black indented sides into the boiling mass below (*see Lign.* 186). The existence of these conical craters led us to conclude, that the boiling cauldron of lava did not form the focus of the volcano, but that this liquid mass was comparatively shallow, and the basin which contained it separated by a stratum of solid matter from the great volcanic abyss, which constantly poured out its melted contents through these numerous craters into this upper reservoir. We were further inclined to this opinion from the vast columns of vapour continually ascending from the chasms in the vicinity of the sulphur banks and pools of water, for they must have been produced by other fire than that which caused the ebullition in the lava at the bottom of the great crater; and also by noticing a number of small vents in vigorous action high up the sides of the great gulf, and apparently quite detached from it. The streams of lava which they emitted rolled down into the lake, and mingled with the melted mass, which, though thrown up by different apertures, had perhaps been originally fused in one vast furnace. The sides of the gulf before us, although composed of different beds of ancient lava, were perpendicular for about 400 feet, and rose from a wide horizontal ledge of solid black lava, of irregular width, but extending completely round. Beneath this ledge the sides sloped gradually towards the burning lake, which was, as nearly as we could judge, three or four hundred feet lower. It was evident that the large crater had been recently filled with liquid lava up to this ledge, and had, by some subterranean channel, emptied itself into the sea, or upon the low land on the shore; and in all probability, this evacuation had caused the inundation of the Kapapala coast, which took place, as we afterwards learned, about three weeks prior to our visit. The grey, and in some places apparently calcined sides of the great crater before us—the fissures which intersected the surface of the plain on which we were standing—the long banks of sulphur on the opposite sides of the abyss—the vigorous action of the numerous small craters on its borders—the dense columns of vapour and smoke that rose out of it, at the north and south ends of the plain, together with the ridge of steep rocks by which it was surrounded, rising three or four hundred feet in perpendicular height—presented an immense volcanic panorama, the effect of which was greatly augmented by the constant roaring of the vast furnaces below."*

17. MR. STEWART'S VISIT TO KIRAUEA. — In June 1825, Mr. Stewart, accompanied by Lord Byron, and a party from the *Blonde* frigate, went to Kirauea, and descended to the bottom of the crater.

"The general aspect of the crater," observes Mr. Stewart, "may be compared to that which the Otsego Lake would present, if the ice with which it is covered in winter were suddenly broken up by a heavy storm, and as suddenly frozen again, while large slabs and blocks were still toppling, and dashing, and heaping against each other, with the motion of the waves. At midnight the volcano suddenly began roaring, and labouring with redoubled activity, and the confusion of noises was prodigiously great. The sounds were not fixed or confined to one place, but rolled from one end of the crater to the other; sometimes seeming to be immediately under us, when a sensible tremor of the ground on which we lay took place; and then again rushing on to the farthest end with incalculable velocity. Almost at the same instant a dense column of heavy black smoke was seen rising from the crater directly in front, the sub-

* Ellis's Polynesian Researches, vol. iv.

terranean struggle ceased, and immediately after, flames burst from a large cone, near which we had been in the morning, and which then appeared to have been long inactive. Red-hot stones, cinders, and ashes, were also propelled to a great height with immense violence; and shortly after, the molten lava came boiling up, and flowed down the sides of the cone and over the surrounding scoriæ, in most beautiful curved streams, glittering with a brilliancy quite indescribable. At the same time, a whole lake of fire opened in a more distant part. This could not have been less than two miles in circumference, and its aspect was more horribly sublime than any thing I ever imagined to exist, even in the ideal visions of unearthly things. Its surface had all the agitation of the ocean; billow after billow tossed its monstrous bosom into the air; and occasionally those from different directions burst with such violence, as in the concussion to dash the fiery spray forty or fifty feet high. It was at once the most splendid and fearful of spectacles."*

18. The Volcano of Jorullo.—In South America volcanic action has been, and is still, exerted over an immense extent of country; and the vents of the subterranean fires extend to the loftiest summits of the Andes.

In the parallel of the city of Mexico there are no less than five burning mountains—Tuxtla, Orizaba, Popocatepetl, Jorullo, and Colima—arranged as if they originated in an immense fissure, traversing the region from east to west, and extending from sea to sea.

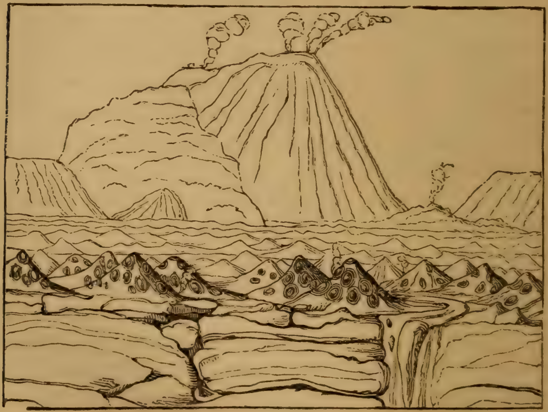
The elevated country which constitutes the province of Quito, is, as it were, an arch or dome, spread over an immense focus of volcanic energy, whose channels of communication with the atmosphere are the burning mountains of Pichincha, Cotopaxi, and Tunguragua; which by their grouping, as well as by their lofty elevation and grand

* Lord Byron's Voyage in the Blonde frigate. See Appendix A.

outline, present the most sublime and picturesque aspect which is any where concentrated within so small a space in volcanic landscape.*

Eruption of Jorullo. South America has been the theatre in modern times, of one of the most extraordinary revolutions in the annals of the physical history of our planet,—that which gave rise to the burning mountain of Jorullo.†

In Mexico there is an extensive plain called the *Malpays*, which was covered by fields of cotton, sugar-cane, and indigo, irrigated by streams, and bounded by basaltic mountains, the nearest active volcano being at the distance



LIGN. 187.—VOLCANO OF JORULLO, MEXICO.

(*By Baron Humboldt.*)

of eighty miles. This district is situated at an elevation of about 2,600 feet above the level of the sea, and was

* Cosmos, p. 229.

† Baron Humboldt's Nouvelle Espagne; see also his Vues des Cordillères, for beautiful illustrations of Jorullo and its hornitos.

celebrated for its beauty and extreme fertility. In June 1759, alarming subterranean sounds were heard, and these were accompanied by frequent earthquakes, which were succeeded by others for several weeks, to the great consternation of the neighbouring inhabitants. In September tranquillity appeared to be re-established, when in the night of the 28th the subterranean noise was again heard, and part of the plain of the Malpays, from three to four miles in extent, rose up like a mass of viscid fluid, in the shape of a bladder or dome, to a height of nearly 1,700 feet; flames issued forth, fragments of red-hot stones were thrown to prodigious heights, and through a thick cloud of ashes, illumined by volcanic fire, the softened surface of the earth was seen to swell up like an agitated sea.* A huge cone, above 500 feet high, with five smaller conical mounds, suddenly appeared, and thousands of lesser cones (called by the natives *hornitos*, or ovens) issued forth from the upraised plain (*Lign.* 187). These consist of clay intermingled with decomposed basalt, each cone being a *fumarole*, or gaseous vent, from which issues thick vapour. The central cone of Jurullo is still burning, and on one side has thrown up an immense quantity of scorified and basaltic lavas, containing fragments of primary rocks. Two streams of the temperature of 186° of Fahrenheit, have since burst through the argillaceous vault of the hornitos, and now flow into the neighbouring plains. For many years after the first eruption, the plains of Jorullo were uninhabitable from the intense heat that prevailed.

19. SUBMARINE VOLCANOES.—Volcanic eruptions take place alike indiscriminately, either on the land or beneath the waters of the ocean. The igneous foci of southern Italy are certainly not confined to the land, but extend beneath the bed of the Mediterranean, of which the appearance of new shoals and islands affords conclusive evidence.

* The tract consisted of porphyritic rocks.

Livy informs us that an event of this kind, which took place about the period of the death of Hannibal, together with other volcanic phenomena, so terrified the Roman people, as to induce them to decree a supplication to the gods, to avert the displeasure of heaven, which these prodigies were supposed to denote. "Nuntiatumque erat haud procul Siciliâ insulam quæ nunquam ante fuerat novam editam e mari esse."—LIVY, lib. xxxix. c. 56.

In Iceland, which may be regarded as a submarine volcanic mountain, with the highest summits above the waters, eruptions are not restricted to the area of dry land; but often burst out in submarine volcanoes off the coasts. The enormous eruptions which issued from three different vents in the low tract called Shaptar Jokul, in 1783, and poured out lava currents many miles wide, and ninety long, was preceded by the appearance of volcanic cones, vomiting flames and vapour, in the neighbouring sea, many miles from the land.*

A highly interesting example of the emergence of a submarine volcano took place in 1831. A volcanic island suddenly arose in the Mediterranean, about thirty miles off the S.W. coast of Sicily, where previous soundings had ascertained the depth of the sea to be 600 feet. It was preceded by a violent spouting up of steam and water, and at length

* Travels in Iceland, by Sir G. S. Mackenzie.

It is worthy of remark that there are active volcanoes both in the Arctic and Antarctic regions. Sir James Ross observes, that "the earth's crust, as we approach towards the pole in the southern hemisphere, presents the most striking indications of the vast subterranean fires pent up within it, and, as we now find, having vent in both the frigid zones: the volcano of Jan Mayen actively burning within the Arctic Circle; and Mount Erebus, rising from the lofty mountain range of the newly-discovered continent of Victoria, to an altitude of more than 12,000 feet above the Antarctic Ocean, and sending forth its smoke and flame to the height of 2,000 feet above its crater, the centre of volcanic action in those regions of eternal snow."—*Sir J. C. Ross's Voyage to the Southern Seas*, vol. ii. p. 412.

a small island gradually appeared, having a crater on its summit, which ejected scoriæ, ashes, and volumes of vapour ; the sea around was covered with floating cinders and shoals of dead fishes. The crater attained an elevation of nearly 200 feet, with a circumference of about three miles, having a circular basin full of boiling water of a dingy red colour. It continued in activity for three weeks, and then gradually disappeared. In 1833, two years after its destruction, a

LIGN. 188.—VOLCANIC ISLAND THROWN UP IN THE MEDITERRANEAN IN 1831.

dangerous reef remained, eleven feet under the water ; in the centre of which was a black volcanic rock (probably the remains of the solid lava ejected during the eruption), surrounded by shoals of scoriæ and sand. Its appearance, when visited by M. Constant Prévost, is shown in this sketch (*Lign.* 188), from a drawing with which he favoured me. From these facts it is certain that a hill, 800 feet high, was here formed by a submarine volcanic vent in the course of a few weeks. The occurrence of shoals of dead fish will not fail to remind you of the ichthyolites of Monte Bolca (*ante*, p. 265): and there can be no doubt that vast numbers were engulfed in the erupted mineral masses at the bottom of the sea; and when this ocean-bed shall be elevated above the waters, and explored by some Agassiz of future times, the then fossil fish of the Mediterranean, imbedded in volcanic tuff, will afford interesting subjects for the contemplation of the geologist and the philosopher.

20. Summary of Volcanic phenomena.—I have indulged in these long extracts, because the vivid pictures which they present of volcanic action, cannot fail to produce a powerful impression on the mind, and cause it to revert to the principles enunciated in the first Lecture, which suggest the probability that the earliest condition of the earth, and of the worlds around us, may have been that of vapour or fluidity (*ante*, p. 48). Here we see the most solid and durable materials of the globe reduced to a liquid state—seas of molten rocks, with their waves and billows, their surge and spray, giving birth to torrents and rivers, which, when cooled, become the hardest and most indestructible mineral masses on the surface of our planet!

The constant escape of aeriform fluids from volcanic vents—the irresistible force which such elastic vapours exert when pent up and compressed—an effect with which our steam-boats and locomotive engines have made every one familiar; and the immense production of such gaseous elements which must be taking place in the interior of the globe, from the igneous action which is going on unremittingly, afford a satisfactory explanation of the nature and cause of earthquakes, and of those elevatory movements by which the foundations of the deep are broken up, and raised into chains of mountains, thousands of feet above the level of the sea. The volcanic vents are, in fact, the safety-valves from which the caloric and gaseous fluids from the interior of the earth escape into the atmosphere; when these channels become choked up, the confined gases occasion earthquakes, dislocations of the rocks and strata, and elevations of the land, and at length escape either through the former vents or by opening new channels. Hence, in the language of Humboldt, the volcanic force must be contemplated as *formative* of new rocks, and *transformative* of those which were pre-existing. But the volcanic operations now going on, are only a faintly reflected image of that energy which took place in the earliest geological epochs, under very different terrestrial and atmospheric conditions. The vast chasms and fissures which it is probable existed in the solid portions of the earth's crust in the ancient periods, from the contractions which must have taken place before refrigeration had proceeded so far as to admit of accumulations of aqueous sediments on the primary mineral masses, have since been closed by the protrusion of mountain chains through them, or filled up by dikes of granite, porphyry, and basalt.*

Many ingenious theories have been proposed to account for the immediate cause of volcanic action. Of these, the oxydation of the metallic bases of certain earths and alkalies by percolations of water into deep-seated beds of these substances, suggested by Sir Humphry Davy, is still powerfully advocated by a high authority,—Dr. Daubeny; but proof that such bases do exist in a metallic state in the interior of the earth is required, before the hypothesis, however ingenious, can be admitted as a *vera causa*.† The intense heat and chemical changes which evolve gaseous vapours and fluids, are the first elements in volcanic action; and the volume of gas is often so great as to uplift the molten lava, and at length to burst through and escape in violent explosions. Without being able to determine the precise nature of the first link in the chain of volcanic

* Cosmos, p. 237.

† The phenomena attendant on the combination of oxygen with potassium, sodium, &c.—the rapid and violent evolution of heat, light, and expansive force—mus be familiar to the intelligent reader.

action, we may reasonably infer that the play of electro-chemical or electro-magnetic forces, which must be incessantly going on among the heterogeneous mineral substances of which the earth consists, is fully adequate to produce the varied effects we have been contemplating.*

As the fragments of unmelted rock, which are occasionally thrown up from the foci of volcanoes apparently of enormous depth, consist of granite, quartzose porphyry, and the like, some philosophers are of opinion that a primitive granitic rock was the substratum, and is the support, of the superimposed sedimentary and fossiliferous strata.

21. HYPOGENE ROCKS.†—We must now enter upon a more particular examination of the *Hypogene*, or metamorphic and plutonic rocks; those masses of crystalline minerals, which everywhere manifest the influence of intense heat under great pressure. It will be convenient to consider them under two heads: viz. 1st, the rocks which present a stratified or laminated structure, as mica-schist, gneiss, &c.; 2dly, those which occur in amorphous masses, as granite, porphyry, &c.; including, in this group, the ancient volcanic product, trap or basalt, a notice of which we found it requisite to anticipate, when investigating the fossiliferous strata traversed by dikes of this substance.

And here it is necessary to premise, that an acquaintance with the nature and appearance of the minerals that are the usual components of primary rocks, is indispensable to enable the reader to have a clear conception of the facts that will come under his notice. This knowledge can only be acquired by the study of specimens; and it were useless to attempt by mere description to teach the elements of

* The various theories that have been proposed to explain volcanic action, are considered with great candour and perspicuity by Sir H. de la Beche, in his charming volume entitled, Researches in Theoretical Geology.

† See *ante*, p. 206.

mineralogy. In these Lectures I must assume that such knowledge is possessed by my readers, or that they will rest satisfied with a general idea of the leading phenomena embraced in this division of the subject.*

Mica-schist and Gneiss. The stratified metamorphic rocks consist of two well-defined groups. The first, or uppermost, is *Mica-schist*, a slaty rock, abounding in a mineral called *mica* (from its glittering appearance); and *quartz*, a substance of which rock crystals, and the semi-transparent pebbles common in most beds of shingle or beach, are examples. These two minerals are disposed in alternate layers, forming laminated beds, which are extremely contorted and undulated. The upper divisions of this series bear a considerable resemblance to the metamorphic argillaceous schists; the lower are of a more quartzose character, probably from having been subjected to a greater degree of igneous action.

Gneiss† consists of contorted and laminated beds of quartz, felspar, and mica, irregularly stratified; which may, in truth, be regarded as stratified granite, for the same substances enter into their composition, as prevail in the amorphous masses of that rock. Gneiss is often found associated and alternating with mica-schist, quartz-rock, clay-slate, and a very hard granular rock, called primary limestone. The whole series of stratified metamorphic beds may therefore be considered as partaking of one

* The elementary mineralogical knowledge necessary for this purpose, may be acquired by the study of a suite of specimens to be obtained of Mr. Tennant, 149, Strand, Professor of Mineralogy in King's College. If the student can have the advantage of a few private lessons from Mr. Tennant, or can attend the lectures delivered in King's College, his progress will be more rapid and satisfactory than by any other method. For the advanced student, the "System of Mineralogy," by James D. Dana, second edition, New York, 1844, will be found the best work on the subject.

† A German mining term.

common mineralogical character, and with the exception of the calcareous rocks, may have originated from the disintegration and subsequent consolidation of more ancient primary masses.

There are various substances associated with this group, as steatite, hornblende-schist, chlorite-schist which is a green slaty mineral, and the beautiful mottled magnesian rock called *Serpentine;* the latter is often connected with trap.

Granite (so named from its granular structure), is the foundation upon which all the strata of which we have spoken are superimposed, and the framework of the earth's crust; rising to the loftiest heights, and stretching into mountain chains, which mark the grand natural divisions of the physical geography of the globe.

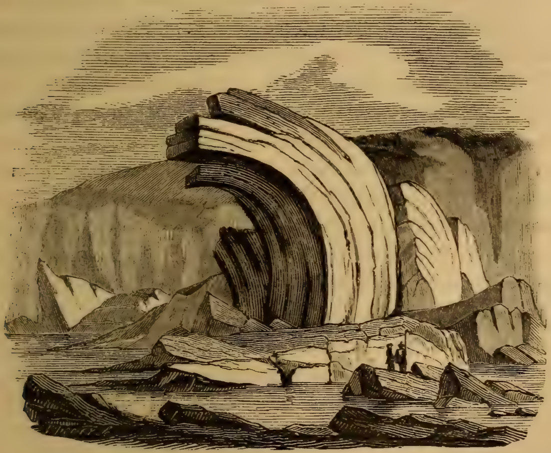
Although presenting great variety in the proportion and colour of its ingredients, granite is essentially composed of three substances, which may be easily recognised in the blocks of which many of our pavements, bridges, roads, and other works, are constructed. These are *mica*, known by its silvery or glittering aspect; *quartz*, by its glassy appearance; and *felspar*, which forms the opaque white, pink, or yellowish masses, oftentimes seen in sections as long angular crystals, which from their size and colour may be readily detected, even by the unscientific observer. In some species of granite, *talc* and *hornblende* occur, and the mica is wanting; these are called *sienite*, or *syenite:* those masses which are composed of crystals of felspar, in a base of earthy felspar, constitute *porphyry*.

M. Bischof states that it may be demonstrated mathematically, that all the sedimentary strata, and all the substances enclosed in drusy cavities, are derived from the plutonic crystalline rocks; these have furnished the materials, and water has conveyed the quartz, calcareous spars, heavy spars, metals, and other substances which fill such cavities.

22. Mica-schist and Gneiss.—These rocks are widely spread over and around the masses of unstratified plutonic rocks. They occur in Caernarvon and Cumberland, but are of inconsiderable extent in England. In Scotland they extend over great part of the Highlands, and largely prevail in the Hebrides; they form the mountain-ranges of the north of Ireland, and cover large areas in Londonderry and Donegal.

The most striking features of these rocks, are the flexures and contortions in which they are so generally folded; proving the soft and ductile state in which the component materials must have existed, for they present every variety of sinuosity and curvature imaginable.

The Isle of Lewis (one of the Hebrides) so admirably



Lign. 189.—Curved Gneiss in the Isle of Lewis.
(Dr. Macculloch's Western Isles.)

illustrated by Dr. Macculloch, is remarkable for the contortions observable in its precipitous cliffs of gneiss, and the innumerable granite veins with which they are traversed. The face of the rocky cliffs appears like veined marbled paper; and the imagination can scarcely conceive an intricacy, or interlamination of this nature, of which a resemblance could not be found in the cliffs of Lewis.*

From the decomposition and falling away of the surrounding parts of the rocks near Oreby, an interesting, perhaps solitary, example occurs, of a bent and detached mass of gneiss, about thirty or forty feet high (*Lign.* 189), and which forms a highly interesting and picturesque object.

The stratified appearance of gneiss and mica-schist is attributed by some geologists to an arrangement of crystals of different specific gravities in horizontal planes; their subsequent softening by heat, admitting of the flexuosities of these rocks; and it is inferred that melted granite, upon cooling under particular circumstances, would assume a stratified appearance, analogous to that of gneiss; or might even resemble the structure of aqueous sediments.

23. Contortions of crystalline rocks.—The curvatures and flexures of rocks, largely composed of quartz, is a subject of great interest in another point of view, because it bears upon the question as to the solution and deposition of silex; a process which appears to have been going on in the crust of the earth from the mode of formation of the most ancient granitic rocks, to the deposits now in progress. I have before remarked, that the appearance of some of the siliceous infiltrations in the tissues of sponges, ventriculites, and other zoophytes, and even in the intimate structure of wood,† when seen under a highly magnifying power, is that of a viscid fluid, or plastic paste, pressed into the interstices of the tissue, rather than that of the percolation of a mineral solution, or of a metamorphism of

* Western Isles, p. 193.

† As for example, in some of the fossil wood from Egypt and Australia. See *ante*, p. 711.

the organism, as in other examples of silicified animal and vegetable structures.

Experiments have shown that melted quartz, unlike alumina, retains its viscidity for some time when cooling, and may be drawn out in threads;* and M. Jobert states, that in graphic granite he has found the quartz crystals in the midst of the felspar flattened and contorted, as if they had been strongly pressed between the felspathic matter.†

These facts seem to offer an explanation of the flexures and curvatures in quartz rocks and gneiss: and they are brought forward by Mr. Darwin, with his usual acumen, to illustrate the origin of the remarkable duplications, and abruptly arched positions, of the stratified quartz rocks in the Falkland Islands. "Some of the hills," he observes, "are composed of quartz strata doubled on themselves, with the axis-plane thrown quite over,—the quartz must therefore have been in a pasty condition when it suffered without fracture such abrupt curvatures." Mr. Darwin states that the detached concentric layers resembled gigantic semi-cylinders of quartz, "like draining or ridge tiles.

* M. Gaudin, quoted by Mr. Darwin.

† The chalcedonic stalactites, which are often found in the hollows of flint and agate nodules, must have been formed by the slow infiltration of silica in a viscid state. M. Alexandre Brongniart attributes the formation of all agates and chalcedonies to the viscous or gelatinous condition of the mineral matter; and that of hyaline quartz and rock crystal to the perfect fluidity of the same. "Lorsque la silice a été complètement dissoute, et par conséquent dans un état de liquidité parfaite, elle a cristallisé et produit le quartz hyalin. Mais lorsqu'elle était en consistance gélatineuse, elle a produit les silex, et surtout ceux qu'on désigne par le nom général d'agate et de calcédoine."—*Essai sur les Orbicules siliceux.* Ann. Sciences Nat. Juin 1831.

In the specimen of Trigonia from Tisbury, previously mentioned (*ante*, p. 520), the *branchiæ* are completely silicified; and some of these processes when examined under a high power, show the orbicular structure which characterizes chalcedonic silica.

One specimen was twenty feet long and twelve in diameter."*

It would appear, therefore, that silex and quartz may be deposited in two ways: by the action of thermal waters (*ante*, p. 94), and by the influence of intense heat. The remark of Professor Keilhau here applies with equal force as to the experiments which called it forth :—" The greater part of the crystalline rocks have an entirely hidden origin and development. Chemistry alone cannot decide this question, for the same minerals can be composed in nature by different processes. By the side of the celebrated fact which showed the possibility of the formation of felspar by heat, we can now place experiments which prove the possibility of producing felspar in the moist way."

The rocks of this system are widely expanded over Europe and America; and everywhere abound in metalliferous veins. They are of various ages; and their metamorphic character is proved by the occurrence of gneiss, mica-schist, and talcose-schist, in the Alps and Apennines, under circumstances showing that their crystalline structure has been acquired since the origin of many of the fossiliferous strata; even in some instances long after the deposition of those which repose directly upon them. On the other hand, " the gneiss of Kinnekulle in Sweden, and of the Falls of Montmorenci, and many of the plutonic rocks of the Aidarondach mountains west of Lake Champlain, are of older date than any strata in which organic remains have yet been found." †

24. BASALT, OR TRAP.—The consideration of the ancient volcanic rock, designated by the various names of *Whin*, *Trap*, *Basalt*, and *Clinkstone*, will next engage our attention. Basalt occurs in veins or dykes, which traverse rocks of all

* Mr. Darwin, On the Geology of the Falkland Islands. Geological Journal, vol. ii. p. 267.

† Mr. Lyell's Travels in America, p. 129.

ages ; it also occurs in layers spread over the surface of the strata, or interposed between them. Many modern lavas differ so little from basalt, that it is unnecessary to adduce proof of the volcanic nature of this rock. Dr. Macculloch observes, that from lava to basalt, and from thence to syenite, porphyry, and granite, there is an uninterrupted succession : *as agents in geological changes trap and granite are identical;* and that it is a mere dispute about terms to refuse the name of submarine lavas to basaltic dikes. "They are as much the product of extinguished volcanoes, although they do not now emit fire or smoke, as are those of Italy, where the volcanic action has ceased."* Beds of basalt, of a friable and coarse texture, are often found in the older rocks ; these are volcanic ashes and grits, that have been formed at the bottom of the sea, during the accumulation of the sedimentary matter with which they are associated (*ante*, p. 779). In some places they appear as currents or sheets of pure volcanic materials; at others they envelope marine remains, pebbles, sand, and fragments of rocks: some layers consist of fine volcanic scoriæ passing into sand ; and all these varieties alternate with beds composed exclusively of shelly and marine sediments, so that no doubt can be entertained that the diversified masses thus arranged in parallel strata, must have been formed during the same period of igneous action. These evidences of ancient volcanic operations are similar to those observable in the modern deposits of Sicily, where banks of existing species of marine shells, now at considerable heights above the sea, are so intercalated with volcanic matter, that no other inference can be drawn than that the whole were of contemporaneous marine formation.†

The most remarkable form assumed by basalt, is that of regular pillars, or columns, clustered together ; a character also observable in some recent lavas ; the columnar basalts

* System of Geology, vol. ii. p. 100. † Silurian System, p. 75.

of the tertiary epoch have already been noticed (*ante*, p. 271). This columnar structure has been proved by some highly interesting experiments, to have originated in the manner in which refrigeration took place. Mr. Gregory Watt * melted seven hundred weight of basalt from Rowley Regis (*ante*, p. 774), and kept it in the furnace several days after the fire was reduced. It fused into a dark-coloured vitreous mass, with less heat than was necessary to melt pig-iron ; as the mass cooled, it changed into a stony substance, and globules appeared ; these enlarged till they

LIGN. 190.—BASALTIC COLUMNS, FROM THE GIANTS' CAUSEWAY.

Fig. 1. A block partially decomposed, exhibiting the primitive spheroidal figure of the prism. 2. Portions of columns, consisting of several joints. 3. The concave surface of a joint.

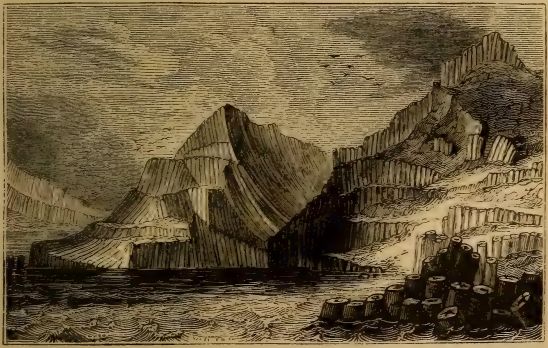
pressed laterally against each other, and became converted into *polygonal prisms.*

The articulated structure and regular forms of basaltic columns have, unquestionably, resulted from the crystalline arrangement of the particles in cooling ; and the concavities, or sockets, have been formed by one set of prisms pressing upon others, and occasioning the upper spheres to sink into those beneath ; thus the different layers of spheres have

* Philosophical Transactions for 1804.

been articulated together, as in the basaltic columns of the Giants' Causeway (*Lign.* 190).

Proofs of the correctness of this inference are afforded by the occurrence of a spheroidal nucleus enveloped by a polyhedral block of basalt; and from the fact, that when this rock is not divided into regular prismatic columns, it often forms laminated spheroids, which, varying in size, constitute by aggregation extensive masses. The position of the columns presents every variety from the perpendicular to the horizontal; this has arisen from corresponding differences in the direction of the cooling surfaces, for the prisms are found to be always at right angles with the surface of refrigeration; the horizontal, inclined, and curved columns of basalt, which occur in the Isle of Staffa, and elsewhere, have originated from this cause.



LIGN. 191.—THE ISLE OF STAFFA.

25. ISLE OF STAFFA: FINGAL'S CAVE.—Many of the Hebrides, or Western Isles of Scotland, are almost wholly composed of trap rocks. Of these Staffa* is the most celebrated, on account of a deep chasm or recess situated in a magnificent group of vertical columnar basalt, and which

* *Staffa*, a Norse term signifying a staff or column.

has been produced by the incessant action of the surges on the base of the cliff. This natural cavern is of singular beauty, and is known to the English tourist by the name of *Fingal's Cave;* but it is called by the islanders, *Naimh-bim,* or the Cave of Music, from the murmuring echoes occasioned by the billows, which in rough weather dash with violence and a loud noise into the chasm.

The Isle of Staffa is a complete mass of columnar basalt; it is about two miles in circumference, and forms a table-land of an irregular surface, being surrounded on every side by steep cliffs, about seventy feet high, which are composed of clusters of angular columns, possessing from three to six or seven sides. It is intersected by one deep gorge, which divides the higher and more celebrated columnar portion from the other division of the island. At the highest tides, the columns which form the south-western cliffs appear to terminate abruptly in the water; but the retiring tide exposes a causeway of broken columns at their base. The greatest elevation of the island is about 120 feet, and its surface is covered with soil of considerable depth, clothed with herbage.*

Fingal's Cave, first made known to the public in 1772, by Sir Joseph Banks, is on the south-east corner of the island, and presents a magnificent chasm 42 feet wide, and 227 in length. The roof, which is 100 feet high at the entrance, gradually diminishes to 50, and is composed of the projecting extremities of basaltic columns; the sides are formed of perpendicular pillars; and the base consists of a causeway paved with the truncated ends of similar columns. The vaulted arch presents a singularly rich and varied effect; in some places it is composed of the ends of portions of basaltic pillars, resembling a tessellated marble pavement; in others, of the rough surface of the naked rock; while in many, stalactites mingle with the pillars in the recesses, and

* Dr. Macculloch.

add, by the contrast of their colours, to the pictorial effect, which is still further heightened by the ever-varying reflected light thrown from the surface of the water that fills the bottom of the cave.

The depth of the water is nine feet, and a boat can therefore reach the extremity of the cave in tolerably calm

LIGN. 192.—FINGAL'S CAVE; VIEWED FROM WITHIN.

weather; but when the boisterous gales of that northern clime drive into the cavern, the agitated waves dashing and breaking against the rocky sides, and their roar echoed with increased power from the roof, present to the eye and ear such a scene of grandeur as bids defiance to any description. The short columns composing the natural causeway before mentioned, continue within the cave on each side, and form a broken and irregular path, which allows a skilful and fearless climber to reach the extremity on the eastern side on foot: but it is a task of danger at all times, and impossible at high tide, or in rough weather.

It would be useless, observes Dr. Macculloch, to attempt a description of the picturesque effect of a scene which the pencil itself is inadequate to portray. Even if this cave were destitute of that order and symmetry, and that richness arising from the multiplicity of its parts, combined with its vast dimensions and simple style, which it possesses, still the prolonged length, the twilight gloom half concealing the playful and varying effects of reflected light, the echo of the measured surge as it rises and falls, the transparent green of the water, and the profound and fairy solitude of the whole scene, could not fail strongly to impress a mind gifted with any sense of beauty in art or in nature.*

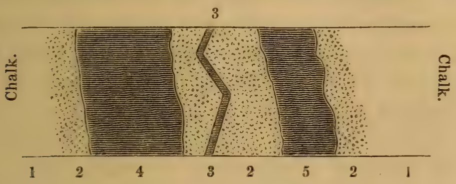
The basalt of which the columns are composed, is of a dark greenish-black hue ; a thin layer of siliceous cement occurs between the joints or articulations, which is called mortar by the islanders, and strengthens their persuasion that this wonderful cave is the work of art. Another cave, but of inferior dimensions, lies at a short distance ; and many others of less note are seen in various parts of the cliffs, into which the sea breaks with a noise resembling that of distant heavy ordnance.

26. STRATA ALTERED BY CONTACT WITH BASALT.—In Ireland a magnificent range of basaltic pillars extends along the northern coast of Antrim. It consists of an irregular group of hundreds of thousands of pentagonal, jointed, basaltic columns, varying from one to five feet in thickness, and from twenty to two hundred feet in height. The structure of these masses I have already described ; their prevailing colour is a dark greenish-grey. Along the shore, a vast area is covered by the truncated ends of upright columns, the upper parts of which have been swept away by the action of the waves. The surface, therefore,

* Macculloch's Western Isles.

presents the appearance of a pavement composed of enormous angular blocks of stone; whence has originated the popular name of the *Giants' Causeway*. In the cliffs, a natural cavern has been excavated by the inroads of the waves, about sixty feet high, and of great picturesque effect; the entrance is nearly thirty feet in width, and the walls are formed of dark basalt.

But the great interest of this spot, in a geological point of view, is the altered structure observable in the sedimentary rocks wherever they are in contact with the basalt. The Chalk in this part of Ireland, constitutes a line of cliffs traversed by trap, which occurs in vertical dikes, and in extensive beds, and has a columnar structure.



LIGN. 193.—TRAP DIKES TRAVERSING CHALK: IN THE ISLE OF RATHLIN.

1. 1. Chalk.
2. 2. 2. Chalk changed into granular marble from contact with the Trap-Dikes.
3. A narrow Trap Dike or vein traversing altered Chalk.
4. 5. Trap Dikes.

The chalk strata have a total thickness of about 270 feet, and rest on a green sandstone, called *mullattoe*, which is the equivalent of the firestone of the south-east of England (*ante*, p. 296); it contains flint nodules, ammonites, belemnites, echinites, terebratulæ, and other usual fossils of the cretaceous formation.

In the Isle of Rathlin, nearly vertical dikes of basalt are seen intersecting the chalk (as in this sketch, *Lign.* 193), which at the line of contact, and to an extent of several feet from the wall of the dike, is completely metamorphosed. Those portions of the chalk which have been exposed to the extreme influence of the trap, are now a dark brown crystalline rock, the crystals running in flakes, like those of coarse primitive limestone ; in the next state the rock is of a saccharine structure—then fine-grained and arenaceous ; a compact variety with a porcellaneous aspect, and of a bluish-grey colour, succeeds ; this gradually becomes of a yellowish-white, and passes insensibly into unaltered chalk.* The flints in the hardened chalk are either of a yellowish, or deep-red colour, and the chalk itself is highly phosphorescent. The fossils are much indurated, but retain their usual appearance.

To the south of Fairhead, in the county of Antrim, syenite traverses mica-schist and chalk, and fragments of the latter are impacted in the erupted mass, being changed into granular marble.† The geological structure of that part of Ireland consists of—1, The underlying rock, Mica-schist ; 2, Coal-shale ; 3, Triassic strata ; 4, Chalk.‡

In this place it is necessary to remind the reader of the examples of intruded basaltic rocks which have been noticed in the former part of this lecture, when treating of the palæozoic formations; viz. the trap of Dudley (p. 774), of the Malverns (p. 761), Abberley Hills (p. 778), &c.; the toad-stones of Derbyshire (p. 684), and the Whin-sill of Yorkshire. The latter is an enormous basaltic dike, which traverses the island from the Tees to Robin Hood's bay, and intersects all the strata from the lowermost beds of the coal-measures to the oolite inclusive.

27. TRAP DIKES IN THE ISLE OF SKY.—In the Isle of

* Dr. Berger on the Geological Features of the North-east of Ireland, Geol. Trans. vol. iii. p. 172.

† The beautiful statuary marble of Carrara is oolitic limestone, metamorphosed by the influence of contiguous igneous rocks.

‡ Mr. Griffiths.

Sky the intrusions of basalt are on a large scale, and present many important and instructive examples of the disturbance and altered character of the sedimentary rocks, that have been exposed to their influence. From the numerous sketches that illustrate Dr. Macculloch's work on the Western Isles,* I have selected the one before us (*Lign.* 194), as exhibiting vertical, oblique, and horizontal veins or dikes; a large mass of trap is seen abutting end-

LIGN. 194.—TRAP-DIKE ON THE COAST OF TROTTERNISH, IN THE ISLE OF SKY.

a, Vertical Trap.
b, c, d, trap-veins sent off from the mass *a*.
e, strata of sandstone.

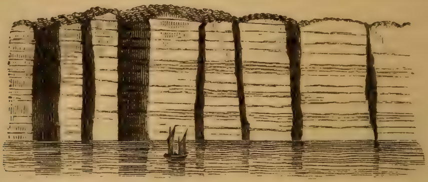
wise at *a*, against the sandstone strata *e*; from which a thick stream flows horizontally, sending off branches both upwards (*b*) and downwards (*d*), and finally dividing into three small veins (*c, c, c*).

In the cliffs at Straithaird, in the Isle of Sky, the sandstone strata are traversed by numerous vertical dikes and veins of trap; and the latter in many places have decomposed, and left perpendicular fissures, as is shown in the annexed sketch (*Lign.* 195); the reverse of the phenomena observable in the Val del Bove (*ante*, p. 829).

Porphyritic dikes and veins also occur abundantly in the same island, in some instances protruding through, and in others spreading over clay-slate, red-sandstone, and shelly limestone.

* This work should be referred to in order to obtain an adequate idea of the extent and complexity of the trap-dikes and veins in the Isle of Sky, and others of the Hebrides.

In some of the slate districts, where the trap has burst through and overflowed the strata, fragments of slate are found imbedded in the basalt, appearing to have been detached from the rock at the intrusion of the lava, and enveloped while the latter was in a state of fusion.



LIGN. 195.—VERTICAL CHANNELS IN SANDSTONE STRATA, left by decomposed trap-dikes; at Straithaird, Isle of Sky.
(*Dr. Macculloch's Western Isles.*)

Sometimes the fractures and displacements of the strata are on so small a scale as to exhibit the relative connexion of the separated portions, as shown in this sketch of trap intruded between sandstone, in the Isle of Arran (*Lign.* 196, *fig.* 4). This island, which is the largest in the Firth of Clyde, presents, like the Isle of Wight in the south-east of England, an epitome of the geology of the neighbouring mainland. "The four great classes of rocks—the fossiliferous, volcanic, plutonic, and metamorphic, are there all conspicuously displayed within a very small area, and with their peculiar characters strongly contrasted."*

28. GRANITE.—Various modifications of the compound mineral termed granite, constitute a great proportion of the primary rocks, and are found almost every where beneath the gneiss and mica-schist, and often in contact with strata

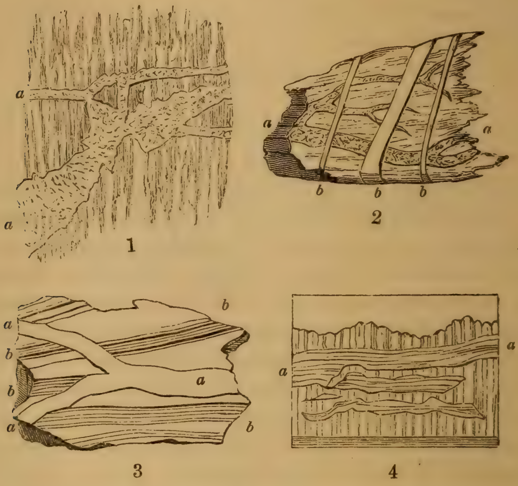
* Mr. Lyell's Elements, vol. ii. p. 371. I much regret that my limits will not admit of a detailed notice of this most interesting Island; and I must refer the reader to the work cited, and to the excellent guide to the Geology of the Isle of Arran by Mr. Ramsay published in Griffiths' Scientific Miscellany, Glasgow, 1841.

of the newest secondary formations. In the British Isles granite appears in Cornwall, Dartmoor, &c.; and forms the nucleus of Skiddaw, Shapfell, Ben Nevis, and other mountain peaks.

Granite veins. Granite often occurs in dikes and veins which traverse not only other rocks, but also the pre-existing masses of granite; proving that the formation of this mineral has taken place at various and distant periods. Veins are fissures or chasms produced in rocks either by mechanical disturbance, or by contraction of the mass during its consolidation or refrigeration, and which have been filled by subsequent infiltration or sublimation, or by injections of mineral matter in a state of fusion from a subterranean source. Although many metallic veins are synchronous with the rocks they traverse, having been formed by segregation during the consolidation of the mass, yet the veins and dikes of volcanic matter are obviously of later origin than the beds in which they are intruded. Thus the granite veins represented in this diagram (*Lign.* 196, *fig.* 1), are newer than the slate rocks through which they are disseminated.

Granite veins traversing other rocks are themselves sometimes intersected by intrusions of other melted materials. This sketch (*Lign.* 196, *fig.* 2) represents a mass of schistose rock, which is crossed by granite veins (*a*, *a*) in one direction, and again by veins of porphyry (*b*, *b*, *b*), which cut through both the schist and the granite. When gneiss is intersected by granite, it becomes shifted, as in this example, in which the granite veins (*Lign.* 196, *fig.* 3, *a*, *a*, *a*) have displaced the laminæ of gneiss (*b*, *b*, *b*). Thus by numerous observations of phenomena of a like nature, it is now clearly established that granite has been ejected during the Cumbrian, Silurian, Carboniferous, Oolitic, Cretaceous, and even Tertiary epochs.

Where granite has been erupted in a fluid or softened state among secondary strata, the latter are invariably altered near the line of junction: but when *consolidated* masses of granite have been protruded, no such change is



LIGN. 196.—INTRUSIONS OF TRAP, GRANITE, PORPHYRY, &c.

Fig. 1. Granite veins (*a, a,*) traversing schist, Isle of Arran.*
— 2. Veins of granite (*a, a,*) traversing schist, themselves crossed by veins of two different kinds of porphyry (*b, b, b*).
— 3. Gneiss (*b, b, b, b,*) shifted by a granite vein (*a, a, a*).
— 4. Intrusion of trap between layers of sandstone (*a, a*), presenting an example of fracture and displacement so small, as to admit of the readaptation of the separated portions.†

observable. Into the slate rocks of the Cumbrian chain, syenite, porphyry, and greenstone, have been injected in a melted state, and now fill up fissures produced during the general movements of those strata; but the central nucleus of primary rock exhibits no such appearance.

* Phillips, Encycl. Metrop.
† Dr. Macculloch, Geolog. Trans. and Western Isles.

29. Granitic eruptions.—In the Isle of Arran, the granitic rocks were evidently erupted in a state of fusion, for the slates are penetrated by veins of granite (*Lign.* 196, *fig.* 1); and in some instances are changed into fine-grained mica, or hornblende slate.

M. Dufrenoy describes granite veins traversing chalk, in the Pyrenees, which have converted the cretaceous rock into crystalline limestone, and generated in it veins of iron-ore; the following instructive fact is noticed by M. Elie de Beaumont. In the environs of Champoleon, where granite comes in contact with Jura limestone, whatever may be the position of the surfaces in contact, the limestone and the granite both become metalliferous near the line of junction, and contain small veins of galena, blende, iron and copper pyrites, &c.; and at the same time the secondary rocks are indurated and crystalline, while the granite has undergone a contrary change.* Mr. Lyell mentions a remarkable example of the alteration induced in stratified rocks by intrusions of syenite or granite; near Christiania, in Norway, very dark-coloured limestone is changed into white crystalline marble, and slate into mica-schist; traces of fossils are not uncommon in some of the crystalline rocks, thus unequivocally proving their metamorphic character.

In Glen Tilt, in Scotland, schist and limestone are superimposed on and traversed by granite, and the latter is intruded among the former rocks, and ramifies into innumerable veins in the most complicated manner, proving its perfect fusion when erupted.†

Granite never occurs stratified, but it often assumes a laminar disposition, which may be considered as a modification of concretional structure. A prismatic or cuboidal form is sometimes observable, but this appears to be the

* Sir H. De la Beche

† See the highly valuable Memoir on the Geology of Glen Tilt, by Dr. Macculloch, Geol. Trans. vol. iii. (first series) pp. 259-337.

result of incipient decomposition, for the fissures become enlarged by exposure to the air and water, and the rock separates into masses resembling piles of masonry, of which the celebrated *Logan* or *Rocking-stones,* and the *Cheese-wring* of Cornwall, are examples.*

In some instances, a tendency to a columnar arrangement is observable, as in the cliffs near the Land's End, in Cornwall. The granitic porphyry of Corsica (*Napoleonite*) presents an orbicular structure, in which balls or spheroids of concentric and alternate coats of hornblende and compact felspar, are disseminated with much regularity throughout the mass.

The granites of Devonshire and Cornwall are considered by Sir H. de la Beche to have been protruded after the deposition of the coal-measures of Devon, and antecedently to the Triassic series. "They appear to have been thrown up through points of least resistance, in a line extending from the southern part of Devonshire to the Scilly Isles, part having protruded through the weakest places, and the remainder being concealed beneath. From the Scilly Isles to Dartmoor inclusive, there seems to have been the upthrust of one mass, which found points of less resistance amid the superincumbent accumulations, more in some places than in others. As the masses rose, the edges of the detrital, trappean, and calcareous beds against which they pressed, were frequently fractured, and into these fractures the granitic matter was forced, forming veins which can often be traced terminating in fine threads ; so that not only was the pressure great, but the fluidity of the igneous rock sufficient to pass into small rents and crevices."†

A group of plutonic rocks, consisting of granite and syenite protruded through overlying schistose and carboni-

* See Appendix B, on the Logan-stones.

† Memoirs of the Geological Survey of Great Britain.

ferous deposits, and surrounded at their base by Triassic strata, forms the range of hills known as Charnwood Forest, in Leicestershire. The highest ridge, Bardon Hill, is crested with bare and rugged masses of syenite; and in various quarries opened at the base of the hills, interesting sections are exposed of the relative positions of the crystalline masses and the sedimentary strata. This isolated cluster of primary rocks is within a hundred miles of the tertiary deposits of the south-east of England; and at a less distance from the metropolis than any other plutonic region.*

30. METAMORPHISM OF ROCKS.—The transition from granite to porphyritic trachyte, passes through infinite gradations, but all the modifications appear to be referable to the degree of incandescence of the materials, the circumstances under which they were ejected, and their slow or rapid refrigeration. An instructive example of the passage of granite into basalt, described by Dr. Hibbert, will illustrate these remarks. In one of the Shetland Isles, a bed of basalt, extending for many miles, is seen in contact with granite. At a little distance from the junction of the rocks, the basalt contains minute particles of quartz, and these become larger and more distinct as they approach the granite: hornblende, felspar, and greenstone (the latter is a homogeneous admixture of hornblende and felspar) next appear; still nearer, the rock consists of felspar, quartz, and hornblende: and at the line of junction, felspar and quartz form a mass, which requires but the presence of mica to be identical with the granite in which it is insensibly lost.†

Limestone in contact with schist frequently assumes a crystalline structure, as if the same agency which had converted the clay into schist, had extended its influence to the overlying calcareous beds. In the Isle of Man, interesting

* See Excursion to Charnwood Forest: Medals of Creation, vol. ii. p. 974.

† Edinburgh Journal of Science.

examples of this transmutation occur. In some instances the calcareous beds in contact with the fundamental rock of shale, are irregular and perfectly crystalline, but change to a stratified disposition, and earthy texture, in proportion as they are further removed from the schist. In other places, the metamorphosis takes place more gradually, each bed of limestone (*Lign.* 197, *a*, *a*, *a*) losing its stratified character, and becoming irregular and crystalline (*b*) where in contact with the schist (*c*), as is shown in this sketch :

Lign. 199.—Metamorphism of Limestone from contact with Schist: Isle of Man.

*(Dr. Macculloch.)**

a, Stratified limestone ; *b*, Crystalline limestone ; *c*, Schist.

the stratified and unstratified rocks ceasing at length to possess any mineralogical distinction. And it is a remarkable and highly instructive fact, that while in the stratified limestone organic remains occur, they are altogether absent in the crystalline mass.

In the Isle of Anglesea, mountain limestone, full of organic remains, may be traced gradually passing into

* Western Isles.

hardened shale, and finally into hornstone, jasper, and analcime rock containing garnets and copper ore, from an intrusion of greenstone porphyry.*

In the Ural mountains, which form the dividing crest that separates the waters of Europe from those of Asia, the effect of metamorphic action is strikingly displayed. Sir Roderick Murchison emphatically remarks, that the crystalline rocks which form the axis of the anticlinal of the Ural chain are for the most part altered Silurian strata. "In the short space of a mile, you may walk upon the edges of the partially altered beds of grit and schist, until you find them converted into amorphous quartz rock, in contact with highly crystalline greenstone ; a rock which is admitted to be of igneous and intrusive character. Coralline limestone is changed into white and green marble." † The intense plutonic action which effected the disturbance of the rocks of the Urals, has clearly been the cause of the rich mineral productions of those regions, the metallic veins, and the mineralization and metamorphism of the sedimentary strata.‡

31. Precious Stones.—Connected with the changes to which the metamorphic rocks have been subjected is the formation of some of those minerals, which, from their beauty, splendour, and use as ornaments, are termed precious stones. The *Sapphire* and the *Oriental ruby*, or red sapphire, which are prized next to the Diamond, and almost equal that gem in hardness, are found in trap rocks ; and the common *Corundum*, which is a species of the same mineral, and the *Emerald*, occur in granite. The sapphire and ruby are pure alumina crystallized ;§ and the

* Professor Henslow ; Transactions of the Philos. Soc. of Cambridge.

† Geology of Russia, p. 357. ‡ Ibid.

§ The sapphire affords, by analysis, 98·5 of alumina, 0·5 of lime, and 1 of oxide of iron ; the ruby, 90 of alumina, 7 of silex, and 1·2 of oxide of iron.—*Phillips's Mineralogy.*

supposition that they have been formed by intense igneous action, is not only probable, but is rendered almost certain, by the experiments of M. Gaudin, who succeeded in producing fictitious rubies, which in every respect resemble the natural gems. These were formed by submitting alumina, with a small quantity of calcined chromate of potash, to the influence of a powerful oxy-hydrogen blowpipe, by which the materials were melted into a crystalline mass, that presented, when cooled, all the characteristics of the Ruby.

Garnet, is a well-known precious stone, of a rich brownish red colour, and is generally found in plutonic rocks; like the ruby, it has also been made artificially, by exposing its constituents, silicates of alumina, lime, iron, &c., to intense heat. This experiment throws light on the occurrence of garnets in shale, altered by contact with a dike of granite or trap, though altogether wanting in every other part of the rock; a proof that these crystals have been produced by the effect of heat on those parts of the sedimentary deposits which were most exposed to the influence of the erupted mass.*

The production of such crystalline substances, though effected by intense heat, probably depends on the action of electro-chemical currents induced by the high temperature; since M. Becquerel and Mr. Cross have formed without heat, from solutions, by long-continued galvanic action, crystals of quartz, arragonite, carbonates of lime, &c. which the resources of chemistry had failed to yield.†

32. METALLIFEROUS VEINS.—In my description of the fissures observable in consolidated strata, I mentioned that

* Mr. Lyell.

† "Light, Heat, Electricity, Magnetism, Motion, and Chemical-affinity, are all convertible material affections; assuming either as the cause, one of the others will be the effect. These forces in their varied natural action upon the surface of our planet, are continually altering the nature of its external crust."—*Lecture on the Progress o Physical Science, by W. R. Grove, Esq. F.R.S.*

the richest depositories of the metals occur in certain cavities termed metalliferous veins; which are separations in the continuity of rocks, of a determinate width, but extending indefinitely in length and depth, and more or less filled with metallic and mineral substances of a different nature from that of the masses they traverse. These natural stores of hidden treasures are not confined to any epoch or formation, nor to any tracts of country; they are, however, most abundant in rocks that have been exposed to intense igneous action, hence their prevalence in the plutonic: but veins of iron, copper, arsenic, silver, and gold, also occur in tertiary strata (*ante*, p. 284).

Some veins are evidently fissures of mechanical origin, having been opened by elevatory forces; in many instances they have been filled from beneath by the sublimation of metalliferous matter by heat; and in others from the surface, by infiltration, or by various materials deposited by streams, which have flowed into them. But in general, the veins are connected by a gradual mineral transition with the contiguous rock, and appear to have resulted from an electro-chemical separation, or segregation, of certain mineral and metallic particles from the enveloping mass, while it was in a soft or fluid state, and their determination to particular centres. The nature of these veins receives illustration from the nests of spar and other minerals common in masses of trap, and in which there appears to have been no possibility of the introduction of any foreign substance from without.

From the observations of M. Fournet in the mines of Auvergne, it seems probable that in many instances sulphurets of iron, copper, lead, zinc, sulphate of barytes, and other minerals, have been introduced at different periods, by electro-chemical action, accompanied by new fractures and dislocations of the rocks, and the widening of previous fissures.* The observations and experiments of Mr. Fox add

* Mr. Lyell's Anniversary Address.

great weight to the hypothesis which explains the filling up of metallic veins by electrical agency. M. Becquerel remarks, that when a vein is filled either wholly or partially, the transfusion of water from the surrounding rocks would bring electric forces into play, and give rise to decompositions and new combinations of mineral matter. The separation of pure metal from solutions of metallic salts, by galvanic action,—a process familiar to every one, under the name of the *electrotype*,—and from the ore by a modification of the same force, exemplifies the nature of those changes by which native gold, silver, copper, &c. may be produced in the interior of the earth.*

There appear to be certain associations of metallic substances in the veins; as, for instance, iron and copper, lead and zinc, tin and copper; and those ores which are combined with a similar base, as sulphurets, carbonates, phosphates, arseniates, &c. are commonly found together.† The following list shows the geological distribution of a few of the chief metals.

Tin—generally occurs in quartz veins traversing granite and schist. It has not been discovered in a native state, but is commonly found as an oxide, and rarely as a sulphuret. The ores of this metal are of great hardness and specific gravity, and are termed tin-stone. *Wood-tin,* so called from its fibrous structure, and *stream-tin,* are found in the beds of streams and rivulets: they are the alluvial detritus of tin-veins that existed in rocks now destroyed. The *stanniferous* gravel of Cornwall is the debris of pre-existing rocks traversed by tin-veins, and has been formed in the same manner as the auriferous alluvia of Russia. The mines of Cornwall are the most productive in Europe, and have been worked from the remotest historical periods. The Tyrians, as early as the time of Moses, imported tin from that district.

* M. Becquerel has succeeded, by the permanent action of electrical currents only, in separating the metals of silver, lead, and copper, from their ores. The electro-chemical apparatus employed consisted simply of iron, a concentrated solution of sea-salt, and the ore of the metal properly prepared. See notes to Dr. Buckland's Bridgewater Essay.

† Professor Phillips.

Lead.—The ores of this metal are very numerous: and the sulphuret of lead, or *galena,* occurs in primary and secondary rocks. In Derbyshire, the principal veins of lead are in the carboniferous limestone.

Copper—is found in primary and secondary rocks, and in modern deposits; it often occurs *native,* that is, in a pure metallic state, in blocks many tons in weight: its ores, or combinations with other metals and minerals, are very numerous. Cornwall is the principal European repository of this metal.

Gold—exists in granite and quartz rocks. The gold found in the mud and sands of rivers has been derived from veins of that metal which existed in rocks, subsequently broken up and disintegrated: such is the origin of the auriferous sands and alluvia of Russia, which we shall presently describe.

Silver.—This metal is found in transition and primary rocks; often native, but generally in ores associated with arsenic, cobalt, &c. Sulphuret of silver (a combination of metallic silver and sulphur) is the most common ore of this metal. Masses of pure silver, 200lbs. in weight, have been found in Norway. The rich Mexican silver and gold mines are in porphyritic rocks.

Platinum—occurs in the Ural Mountains. This metal combines the lustre of gold and silver with incomparable hardness. A vein has recently been discovered in metamorphic rocks, in the Valley of Drac, in the Department of Isère.

Mercury or *Quicksilver*—is found always liquid when in a metallic state; it is generally obtained from Cinnabar, which is a sulphuret of mercury, and forms beds and veins in gneiss and schist; and in strata of the carboniferous epoch. The mines of Idria in Carniola are the most productive in Europe.

Iron.—The almost universal presence of the ores of iron, and the infinite variety of its combinations, are too well known to require description. Native iron is sometimes found in rocks; but from the rapid oxidation of this metal when exposed to air or moisture, it is seldom met with, except in meteoric stones (*ante,* p. 50).

I will concisely notice a few interesting conditions of some of these metallic substances.

33. Auriferous Alluvia of Russia.—In the highly valuable work of Sir R. Murchison, "The Geology of Russia," there is an extremely interesting description of the auriferous alluvia which annually yield a vast amount of

gold and platinum to the Russian government. These metals are obtained, by washing, from the alluvial deposits, which also abound in the bones of mammoths and other huge extinct pachyderms (see *ante*, p. 154). The gold and platinum have evidently been derived from metalliferous veins that existed in the rocks of the Ural mountains, before that chain was elevated above the reach of alluvial action.

"The auriferous shingle, with its sub-angular fragments, so completely resembles the detritus of lakes, and is so unlike the gravel of sea-shores, that, independently of the absence of any marine remains whatever all along the immediate eastern flank of the Ural Mountains, there can be no hesitation in believing that the gold detritus was accumulated during a terrestrial and lacustrine condition of the surface. Previously to the elevation of the Urals to their present altitude, they constituted a moderately elevated region, which formed the edge of an eastern continent, inhabited by the mammoths and their associates. The extensive areas now covered by auriferous detritus, were probably then occupied by lakes, into which were drifted, in the course of ages, the bones of the large extinct mammalia which inhabited the surrounding plains and hills, and the detritus of the rocks and strata. The sudden upheaval of the Ural crest, which has evidently taken place in a comparatively recent period, broke away the barriers of the lakes, and elevated some masses of their shingly bottoms and shores into irregular mounds, which subsequently became desiccated, and now constitute the auriferous alluvia."*

34. Cupreous deposits.—An illustration of a metallic deposit by the effects of chemical action, without the agency of heat, is afforded by a singular formation of copper ore, which occurs in New Brunswick. In a bed of lignite, which is covered by a few feet of alluvial soil, and rests on a conglomerate, the precise nature of which is not stated, there is a nearly horizontal layer of green carbonate of copper, about eight inches in thickness. The ore is disseminated through the lignite, in the same manner as metallic ores are usually blended with their accompanying vein-stones. This bed bears a close analogy to the modern

* See the Geology of Russia, vol. i. pp. 485—487.

cupreous deposits of Anglesea, and of some parts of Hungary and Spain, where, at the present time, water charged with copper in solution, is by the introduction of iron made to precipitate the former metal. From the stratum of lignite occurring with the copper, and the mode in which the latter is interspersed throughout the mass, it appears that the water in which the vegetable matter floated, was at the same time saturated with a solution of copper, and that both the organic and mineral substances subsided to the bottom together, and formed the singular compound deposit under consideration; over which, probably at a subsequent period, the alluvial covering was drifted.*

Near Perm, in Russia, rich cupriferous grits occur, associated with thin seams of coal and abundance of fossil vegetable remains. The copper ores are frequently found arranged around and in the interstices of the stems and branches of the fossil plants, exhibiting a passage from the common oxide of copper to the grey sulphuret, or copper pyrites; and occasionally to bright green acicular malachite, mixed with crystals of the blue copper ore.†

The beautiful green carbonate of copper, known by the name of *malachite*, has been produced from a cupreous solution by the successive deposition of the metallic carbonate in a stalagmitic form, like the calcareous spar of limestone caverns.‡

35. Transmutation of Metals.—The varied transmutations which metallic substances undergo in their passage from one combination to another—from their condition in the ancient rocks, to that in which they appear in later formations—involve many curious and highly interesting phenomena.

The transmission of iron from great depths to the surface, in a chemical form by means of chalybeate springs, from

* Mining Review, vol. iv. No. 4: by Frederick Burr, Esq.

† Geology of Russia. ‡ Ibid. vol. i. p. 375.

deposits in which that metal was mechanically diffused; and the formation of bog-iron, and of iron-stone, through the agency of vegetable matter (*ante*, p. 739), are familiar examples of these changes, and have suggested to Mr. Hugh Miller one of his happiest illustrations. "How strange, if the steel axe of the woodman should have once formed part of an ancient forest!—if, after first existing as a solid mass in a primary rock, it should next have come to be diffused as a red pigment in a transition conglomerate (*ante*, p. 757)—then as a brown oxide in a chalybeate spring—then as a yellow ochre in a secondary sandstone—then as a component part in the stems and twigs of a thick forest of arboraceous plants—then again as an iron carbonate slowly accumulating at the bottom of a morass of the Coal-Measures—then as a layer of indurated bands and nodules of brown ore, underlying a seam of coal—and then, finally, that it should have been dug out, and smelted, and fashioned, and employed for the purpose of handicraft, and yet occupy, even at this stage, merely a middle place between the transmigrations which have passed and the changes which are yet to come!"*

36. Review of the Hypogene rocks.—Enough has been advanced to convey a general idea of the characters and relations of the primary rocks, and of the changes induced on contiguous sedimentary deposits by their influence, when injected or upheaved in an incandescent state.

The traces of stratification—a structure which we have seen is characteristic of aqueous deposition—are evident in the uppermost metamorphic rocks; and there is also a distant analogy to the alternate depositions of secondary beds, in the succession of different mineral masses, as gneiss, mica-schist, quartz rock, &c. But in the lowermost term of the series, the granite, even these apparent relations to the stratified formations are altogether wanting: and in the amorphous masses, veins, and dikes, we see the effects of

* The Old Red-sandstone, p. 250.

long-continued and intense heat, produced under circumstances which have given to the resulting rocks a very peculiar character.

The transmutation of chalk into crystalline marble—of loose sand into compact sandstone—of argillaceous slate into porcelain jasper—of coal into anthracite—of anthracite into shale and slate—of slate into micaceous schist—of micaceous schist into gneiss and granite—of the latter into trap—and so forth—together with the characters presented by the mineral products of existing volcanoes, prepare the mind to receive without surprise the assertion of an eminent geologist and chemist, M. Fournet; *that all the primary rocks are probably sedimentary deposits metamorphosed by igneous action;* * this opinion, however, is but a modification of that long since expressed by our illustrious countryman, Hutton.

There is one striking deduction which M. Fournet has drawn from the mineralogical character of these rocks, namely, that those masses which, according to our chemical knowledge, would require the most intense and long-continued incandescence for their formation—*i. e.* those in which quartz largely predominates—are precisely those which from their geological position must have been longest exposed to such an agency; hence, in granite the foundation rock, quartz, which is the most infusible and refractory material, largely prevails. The possibility of an earth being converted by intense heat ino the hardest and purest crystal, was shown in the formation of fictitious rubies (p. 866). To the granite succeed rocks in the exact order of their containing less quartz, and being therefore more easily fusible —as granite with a large proportion of felspar, porphyry, serpentine, mica-schist, and clay slate.† If we take these

* The general reader will find an interesting account of M. Fournet's theory in Jameson's Edinburgh Journal, No. 47, p. 3.

† Jameson's Edinburgh Journal, No. 47.

phenomena into consideration, together with the facts previously stated, of the transmutation of one substance into another by the effect of caloric, it appears to me, that in the present state of our knowledge we are warranted in concluding, that all the granite and associated plutonic rocks that are accessible to human observation, are nothing more than sedimentary deposits altered by igneous agency.

But from what source were the most ancient granitic rocks derived—whence originated the materials upon which igneous action exerted its influence, and produced those crystalline masses which are the *Ultima Thule* of geological research? Was granite, as Humboldt has supposed, the basis or framework upon which the first aqueous sediments were deposited?—These are questions which in the present state of our knowledge we are not in a condition to solve; and it does not appear probable, that vestiges of the first dawn of creation upon the surface of our planet will ever be revealed to mortal eye.

37. ORGANIC REMAINS IN THE METAMORPHIC ROCKS ? ?—I have stated, that with the lowermost of the slate rocks, all traces of organization are lost; but this assertion requires some reservation, for, as an eminent geologist has remarked, "with the exception of granite, probably no rock is known beneath which organic remains may not be found."* Let us here resume the inquiry.

From the intense heat to which the metamorphic rocks have been exposed, we cannot, of course, expect to find any organic remains, except such as are formed of materials capable of resisting the effects of that influence. The observations and experiments of the Rev. J. B. Reade have shown, that vegetables possess a structure which is composed of silex, and is indestructible in a common fire.† In

* Macculloch's Western Isles, p. 514.

† See Appendix, to this volume, C, for Mr. Reade's observations and experiments on this subject.

animals, we seek in vain for an elementary tissue capable of resisting the powerful influence of heat, except in those minute beings, the Infusoria, which secrete siliceous cases or shells. The shields of these animalcules, and the tissues of some of the zoophytes, are, indeed, the only animal structures that can escape destruction, in rocks subjected to the effects of a high temperature; for it is clear, that if calcareous skeletons were exposed to intense heat, all traces of organization would be obliterated. It would therefore be hopeless to expect any indications of animal organisms, except of those that were siliceous, in rocks where even the lines of stratification are melted away.

M. Ehrenberg, to whom we are so greatly indebted for opening this new field of inquiry, has discovered the remains of Infusoria, not only in aqueous but also in volcanic products. The ferruginous or ochreous film or scum, seen on the waters of marshes and of stagnant pools, or collected at the bottom of ditches, sometimes forming a red or yellowish mass many inches thick without any consistence, which divides upon the bare touch into minute atoms, and when dried resembles oxide of iron, is found to be wholly composed of the shields of animalcules (*Gaillonella ferruginea*): and the formation of bog iron-ore is supposed to be in a great measure dependent on these animals. A ferruginous mass from a peat-bog, "which appears to have owed its origin to the action of volcanic heat at the bottom of the sea, entirely consisted of shields of *Naviculæ*." The semi-opal, and the tripoli of the tertiary deposits, are wholly composed of fossil remains of this kind; and Ehrenberg distinctly states, that while in the instances above mentioned, there cannot be the least doubt of the nature of the organic remains, in the semi-opal of the *Serpentine* of Champigny, and in the *precious opal of the porphyry*, he has detected bodies so exactly similar, that although at present he hesitates positively to affirm that they are organic, he can scarcely entertain any doubt upon the subject.

38. CHRONOLOGY OF MOUNTAIN-CHAINS. — We have seen that the intrusions of molten rocks have not only altered the chemical nature of the strata through which they were erupted, but have also changed their positions and relations, and produced corresponding modifications in the physical geography of the dry land; having in some instances transformed plains into mountain-peaks, and in others occasioned the subsidence of elevated regions to the bottom of the ocean. As these changes took place at various epochs, separated from each other by periods of repose, sometimes considerable, sometimes brief, it is manifest that the existing mountain-chains are of very different ages. By a careful examination of the phenomena which bear upon this question, the relative antiquity of many of the principal ranges has been determined ; or, in other terms, it has been ascertained during what geological epochs the Alps, Pyrenees, Andes, &c. were elevated above the waters.

My observations on this subject must, however, be restricted to an explanation of the mode of induction employed, and a brief notice of some of the results. The positions of the older secondary strata in relation to the protruded plutonic rocks and the newer sedimentary deposits, are the principal data by which this problem may be solved ; for, as the secondary and tertiary formations have been deposited in directions either nearly or entirely horizontal, it is obvious, that when they are found highly inclined, and in contact with mountain masses of primary or volcanic rocks, the latter must have been protruded *since* the sedimentary were formed, and of course during the secondary or tertiary epochs, as the case may be. On the contrary, if we find other strata in contact with the same masses, but only touching them with their edges, or encircling their base in an unconformable position, it is evident that the mountains must have been elevated before the formation of the latter deposits.

It is by cautious inductions of this kind, that a distinguished savant, M. Elie de Beaumont, has shown,—1. that the mountain-chains of Erzgebirg, in Saxony, and of the Côte d'Or, in Burgundy, are newer than the Jura limestone, but older than the greensand and chalk. 2. That the Pyrenees and Apennines are of about the same age with the chalk formation. 3. That the western part of the Alps is of later origin than the older tertiary formations, and was raised up after the last of the newer pliocene were deposited.

The Caernarvon chain was elevated anterior to the deposition of the mountain limestone, for the latter wraps round it like a mantle.*

Professor Phillips infers, that when the Grampian hills sent forth streams loaded with detritus to straits where now the valleys of the Clyde and Forth meet, the greater part of Europe was beneath the sea. For the Pyrenees and Carpathian mountains are younger than the Grampians and the Mendip hills.

That the *sudden* protrusion of such immense masses as the Alps or Pyrenees from the bottom of the ocean, must have dislodged vast volumes of water, and created a series of waves high and powerful enough to cause transitory but destructive inundations over such portions of the adjacent dry land as were only a few hundred feet above the level of the sea, cannot be doubted ; but if the elevations were gradual, such effects would take place only in a very slight degree.

39. Systems of Elevation.—From the facts and observations that have been adduced, it is sufficiently obvious

* Professor Sedgwick.

that prodigious masses of granite and other hypogene rocks, have been raised into ridges and mountain-chains, at various periods, and long after their first formation and subsequent consolidation. In many cases the protrusions are local and of comparatively small extent, at least so far as their distribution on the surface is concerned ; for very distant isolated peaks of plutonic matter may have a deep-seated connexion. But in other instances the elevatory force has embraced a vast area, and entire mountain-chains have been simultaneously and permanently lifted up, and now remain in parallel ranges ; the subordinate parts of any one period or system of elevation, being in accordance as to position and direction with the principal upheaved masses. Admitting the general correctness of these views, it follows that mountain-ridges composed of vertical or highly inclined beds, emerging from beneath horizontal deposits, must have been thrown up subsequently to the deposition of the latter : and that their upheaval was succeeded by a long period of repose, during which the flanks of the mountains beneath the sea were covered by the horizontal sediments ; the latter, elevated above the waters, by subsequent movements, now form the fertile plains which surround the base of the Alpine districts.

Professor Sedgwick remarks, that if we admit that the higher regions of the globe have been raised from the sea by any modification of volcanic force, we must also admit that there have been many successive epochs of extraordinary plutonic energy, separated from each other by long periods of repose.* The sudden formation of mountain-peaks by violent upbursts of subterranean force, may be regarded as paroxysmal efforts of the expansive power, by whose long-continued and imperceptible action the elevation of continents, and of

* Anniversary Address to the Geological Society, for 1831.

extensive areas of the bed of the ocean, is gradually effected.*

40. THE CALEDONIAN VALLEY.—The British Islands afford striking illustrations of the long-continued parallelism in the direction of the disturbing forces. The great Caledonian Valley or Glen extends through Scotland almost in a straight line, from S.W. to N.E. from near Lismore Island to Fort George in Moray Frith; a distance of more than a hundred miles. This magnificent glen, with its system of rectilinear lochs or lakes, and friths, has been produced by a wedge-shaped ridge of gneiss having been upheaved in a solid mass, and forced through the stratified deposits which now abut against it in highly inclined positions. That this vast ridge of plutonic matter was in the state of a hard rock when elevated, is inferred from there being no interpolations of volcanic products among the contiguous Devonian strata; and from the latter manifesting no indications of the changes which would have been induced by intense heat. Hence the sharp mountain-ridges and peaks of these Alpine regions, the precipitous glens, the narrow passes, and the deep lochs studded with islands, presenting every variety of combination and contrast of rock, and wood, and water, which constitute the sublime and magnificent scenery of the Highlands.

Now, by a reference to a geological map of England and Scotland, it will be seen that the principal mountains or ridges of elevation of these countries, extend in a line nearly parallel with the direction of the Caledonian Valley, from the Atlantic to the German Ocean. As, for example, the Grampians, which have thrown up the Devonian strata on their southern flank; the nearly parallel range of the great coal-field of Scotland; the Cumbrian and Silurian

* See Mr. Bakewell's sagacious commentary on this question Introduction to Geology, p. 531.

of the south of Scotland; and successively the principal secondary groups of England. "In all," as Mr. Miller observes, "there is an approximation to parallelism with the Caledonian Valley, affording proof that this was the general direction of the elevatory force, during all the immensely-extended term of its operations, and along the entire length of the Island."*

41. Structure of Ben Nevis.—Though all granitic rocks are of the same general character as to structure, composition, and formation, they belong to different epochs; and when in juxtaposition, or intercalated with sedimentary beds, their relative age may be determined as we have previously explained. Even when these aids are wanting, different epochs of eruption are sometimes indicated, by variations in the mineral aspect of the rocks; and I will conclude this subject with a short notice of a highly illustrative example.

Ben Nevis, the monarch of the Scottish mountains, is situated on the southern border of the great Caledonian Valley, suddenly rising up in imposing grandeur from the low country, to an altitude of 4,370 feet above the level of the sea. The base and lower portion of the mountain are composed of gneiss and mica-schist; above and *within* which is a zone of granite; and *within* the latter, and rising out of it, is a central, naked, rocky prism of porphyry, which is the nucleus, and forms the highest peaks of the mountain.

The inference as to the relative age of these three different masses of plutonic rocks from their order of superposition, is the very reverse of that deducible from such an

* The Old Red-sandstone, p. 105. "It is a fact not unworthy of remark, that the profound depths of Loch Ness were affected by the great earthquake of Lisbon in 1755 (*ante*, p. 809); and that the impulse, true to its ancient direction, drove the waves in long furrows to the north-east and south-west."—See Appendix, D.

assemblage of sedimentary strata. In the present case the outer or overlying gneiss and mica-schist that envelope the lower region of the mountain are the most ancient; the granite is the next in age, having protruded through, and upheaved the gneiss; and the central nucleus of porphyry is the youngest, or last erupted rock, having been forced up through the dome of granite. These three phases of plutonic action may have taken place at different and very distant periods; in like manner as the beds of tuff and scoriæ of Vesuvius or Etna, ejected a thousand years ago, may be upheaved and traversed by the modern eruptions of incandescent lava.

42. Retrospect.—I now approach the termination of this argument, and it will be instructive to review the phenomena which have passed before us, in order that we may retain a clear conception of the leading principles and inferences that have been enunciated. I shall, therefore, in the first place, offer a summary of the most important changes which have taken place in the animal and vegetable kingdoms, and in the physical conditions of the earth's surface, during the vast periods which our investigations have embraced; and conclude with a retrospective survey of the effects of vital action in the elaboration of the solid materials of the crust of the globe.

With the view of recalling the principal facts, I now place before you the series of Illustrations employed in these Lectures, that you may perceive at a glance the striking contrast presented by the Faunas and Floras of the respective geological epochs.* In the first stage, traces of the existing species of animated nature were everywhere appa-

* The reader may realize this idea by referring to the illustrations of these volumes, commencing with the fossil human skeleton (*ante*, p. 88), and proceeding from the large mammalia (pp. 151, 176), to the last of the series, the fossils of the palæozoic deposits (pp. 736, 761, 790).

rent; and works of human art, with the bones of man and the remains of contemporaneous animals and vegetables, were found in the modern deposits. In the preceding era (the *Eocene tertiary*) many existing species and genera, of plants and animals, were absent. Large terrestrial pachydermata greatly predominated, and the vegetation was principally of a character referable to temperate and intertropical climes; while the seas abounded in fishes, crustaceans, and mollusca, as at the present time.

The next epoch (the *Cretaceous*) presented one wide waste of waters, teeming with the general types of marine beings, but of different species and genera to those of the later eras, and bearing a large proportion of extinct cephalopodous mollusca. Algæ and fuci made up the marine flora; and drifted trunks of coniferæ and dicotyledonous trees, and a few reptiles, were the only indications of the dry land and its inhabitants. The delta of a vast river now appeared (the *Wealden*), containing the spoils of an extensive island or continent; and the remains of colossal reptiles, and of extinct tropical plants, marked the era of the country of the Iguanodon.

We were then conducted to other seas (the *Oolite* and *Lias*), whose waters abounded in fishes and mollusca, and were inhabited by marine reptiles, wholly unlike any that now exist; while the dry land was tenanted by enormous terrestrial and flying reptiles, marsupial animals and insects, and possessed a tropical flora of a peculiar character.

The succeeding era disclosed extensive regions, covered by a luxuriant vegetation (the *Carboniferous*); with groves and forests of palms, arborescent ferns, and coniferæ, and gigantic trees related to the existing club-mosses and equisetaceæ; the numerical preponderance of the flowerless plants, constituting a botanical character unknown, with but one exception, in modern floras. The ocean abounded in mollusca, radiaria, and crustacea, of genera and species, unlike any that previously appeared.

We advanced to other oceans (the *Palæozoic*), swarming with polyparia, mollusca, radiaria, and fishes, which bore some analogy to those of the preceding seas, but belonged to different genera: and containing interspersions of cryptogamous plants, and relics of a terrestrial flora related to the carboniferous. But as we proceeded in a descending order, traces of animal and vegetable existence became less and less manifest, and were at length reduced to a few shells, corals, and sea-weeds; these finally disappeared, and dubious vestiges of infusoria were the last indications of organic life.

43. SUCCESSIVE CHANGES IN THE ORGANIC KINGDOMS.—If we reverse the order of our retrospective survey, and pass in succession from the most ancient to the modern deposits—from the regions of sterility and plutonic action, to those in which animal and vegetable life were profusely developed—we obtain the following results:—

Geological Formations.	Character of the Fossil Fauna.	Character of the Fossil Flora.
HYPOGENE ROCKS	*Infusoria* ??	No traces of vegetable matter.
CUMBRIAN SYSTEM	*Corals* and *shells*, (*brachiopoda*)	Fuci ?
SILURIAN SYSTEM	Corals, crinoidea, *orthocera*, and other shells; *Trilobites*, *Fishes*	Fuci.
CARBONIFEROUS SYSTEM	Corals, crinoidea, cephalopoda, shells, both marine (chiefly brachiopoda) and fresh-water; trilobites. *Insects*, *sauroid Fishes*, *Reptiles ? Birds* ???	Many hundred species of plants; the *vascular cryptogamia* largely developed. Palms, tree-ferns, coniferæ. Dicotyledonous plants very rare.

Geological Formations.	Character of the Fossil Fauna.	Character of the Fossil Flora.
SECONDARY FORMATIONS . .	Corals and shells of all orders; crinoidea, fishes, insects, belemnites, ammonites, &c. *Reptiles*, both marine and terrestrial, of numerous genera and species; and many of gigantic size. Two or three genera of *Mammalia:* and one of *Birds—Ardea?* . .	Palms. Tree-ferns. Coniferæ, and Cycadeæ. Dicotyledonous trees rare.
TERTIARY . .	*Terrestrial herbivorous* and *carnivorous Mammalia.* The numerical proportion of reptiles comparatively small. *Monkeys*, Birds, Fishes, and all the existing orders . .	Dicotyledonous trees prevail; coniferæ; palms, tree-ferns, &c.
MODERN EPOCH .	MAN, and contemporary animals	The existing vegetation.

This sketch presents but an outline of the most striking changes observable in the succession of organic beings preserved in the respective formations. In this view—setting apart the infusoria—a few fuci, mollusca, and polyparia, are the first evidence of organic existence; these are followed by a large increase of the same orders, and the addition of crinoidea, crustacea, and fishes; in the succeeding period reptiles and insects appear, with sauroid fishes, and an immense development of vegetable forms, particularly of the cryptogamic class. Large reptiles next prevail to an extraordinary degree; and doubtful indications of birds, and a few very small mammalia, attest the existence of the higher orders of animals. The vegetable kingdom is greatly modified; and plants and trees of the coniferous tribes preponderate. The next remarkable change is in the sudden increase of mammiferous animals, and the reduction of the reptile tribes; the large extinct pachydermata, as the mammoth, mastodon, &c. associated with existing genera and species, first appear. From this period to the creation of Man, there are no striking general modifications in the various orders of animal and vegetable existence.

Hence, according to our present palæontological knowledge, the first appearance of certain classes and orders of animals was in the following chronological order:—

Cambrian and Silurian Epochs . .	Fishes; principally *heterocercal* forms. Invertebrata: Mollusca. Crustacea. Annelida. Radiaria. Polyparia.
Carboniferous	Reptiles?? (*ante*, p. 742). Insects.
Permian . .	Reptiles.
Triassic . . .	Fishes; *homocercal*. Birds???—inferred from bipedal imprints of dubious origin (*ante*, p. 556).
Oolite . . .	Mammalia: a few very small forms, of two or three genera (*ante*, p. 510).
Wealden . .	Birds?—a few detached bones (*ante*, p. 440). Terrestrial herbivorous saurians.
Tertiary: Eocene deposits	Mammalia, Cetacea, and Birds, of different orders.
Post-tertiary .	Man.

It is worthy of remark that the *Invertebrata* first appear in groups, and the *Vertebrata* in single orders; and that no land shells, nor any large herbivorous terrestrial animals, except the Iguanodon, occur in strata older than the Tertiary.

It was from this *apparently* successive development of living beings, from the most simple to the most complex organizations, that the geological theory which once prevailed took its rise;* but I scarcely need remark, that the facts we have stated warrant no such inference: for many of the fossil animals which appear in the most ancient or

* See Organic Remains of a Former World, vol. iii. p. 449.

earliest strata, belong to orders having a highly developed organization. Nor does the vegetation of those remote periods lend any support to such a hypothesis ; fungi, lichens, hepaticæ, and mosses, do not form the flora of the palæozoic epochs, but coniferæ, and the most perfectly organized of the cryptogamic class.

44. Geological effects of dynamical and chemical action.—The physical changes that have taken place on the earth's surface, are in perfect harmony with the modifications observable in animated nature; for the laws of mechanical and chemical action are inseparably connected with those which govern vital phenomena; and we have incontrovertible evidence, that throughout the vast periods over which our observations have extended, the same causes have operated, the same effects followed. Thus, heat and cold, drought and moisture, and other meteoric influences, have denuded the loftiest peaks—rivulets and torrents have eroded the sides of the mountain-chains—streams and rivers have worn away the plains, and transported the spoils of the land into the bed of the ocean—the waves of the sea have wasted its shores, and destroyed the cliffs and rocks which opposed their progress—silt has been changed into clay—calcareous mud into limestone—sand into sandstone—pebbles into conglomerates and breccia—and animal and vegetable remains have been imbedded, and added to the mineral accumulations of the past ages of our planet.

Beneath the surface, the action of electro-chemical forces has been alike unintermitting—vegetable matter has been converted into bitumen, coal, amber, and the diamond—earth into crystals—limestone into marble—clay into slate, and sedimentary into crystalline masses traversed by metalliferous veins ; the volcano has poured forth its rivers of molten rock—the earthquake rent the solid crust of the globe—beds of seas have been elevated into mountains—

subsidences of the land and irruptions of the ocean have taken place—and the destructive and conservative influences of caloric and of water have been constantly exerted; the phases of action have alone differed in duration and intensity.

> "Ages have rolled their course, and Time grown grey—
> The earth has gathered to her womb again,
> And yet again, the myriads that were born
> Of her uncounted, unremembered tribes.
> The seas have changed their beds—th' eternal hills
> Have stooped with age—the solid continents
> Have left their place—and Man's imperial works,
> The toil, pride, strength of kingdoms, which had flung
> Their haughty honours in the face of Heaven,
> As if immortal—have been swept away."
>
> HENRY WARE.

45. STRATA COMPOSED OF ORGANIC REMAINS.—In a previous discourse (*ante*, p. 657), I dwelt upon the highly interesting subject of the elaboration of calcareous and siliceous strata from gaseous and fluid elements by vital action, and the formation of islands and continents by the agency of countless myriads of living instruments. Let us for a moment consider how far the present mineral constituents of the earth's crust have been derived from organized beings. The strata of vegetable origin consist of peat, of forests engulfed by subsidences of the land, or imbedded in the silt and mud of rivers and deltas, or in the bed of the ocean—of the lignite and brown coal of the tertiary deposits—of the coals and shales of the carboniferous strata—and of the silicified and calcified trunks of trees in the tertiary and secondary formations.

But the strata which consist wholly, or in a great measure, of animal exuviæ, are so numerous, and of such prodigious extent, that the interrogation of the poet may be reiterated by the philosopher—

> "Where is the dust that has not been alive?"
>
> YOUNG.

For there is not an atom in the crust of the globe that may not have passed through the complex and marvellous laboratory of life!

Thus we find that all the varied orders of animals, from the Infusoria up to Man, have contributed, more or less, by their organic remains, to swell the amount of the solid crust of the earth. The following table presents a concise view of some of the most obvious examples of this indisputable fact:—

Rocks composed wholly or partly of Animal Remains.

Strata.	Prevailing Organic Remains.	Formations.
Trilobite schist	Trilobites	Silurian system.
Dudley limestone	Corals, crinoidea, crustaceans, shells, &c.	—
Shelly limestone	Brachiopodous shells	—
Mountain limestone	Corals and shells	Carboniferous system.
Encrinital marble	Crinoidea and shells	—
Mussel-band	Fresh-water mussels	—
Ironstone nodules	Trilobites, insects, and shells	—
Lias-shales and clays	Pentacrinites, reptiles, fishes	Lias
Limestone	Terebratulæ, and other shells	—
Lias conglomerates	Fishes, shells, corals	—
Gryphite limestone	Shells, principally gryphites	—
Shelly limestone	Terebratulæ, and other shells	Inferior Oolite
Stonesfield slate	Shells, reptiles, fishes, insects	Oolite
Pappenheim schist	Crustacea, reptiles, fishes, insects	—
Bath-stone	Shells, corals, crinoidea, reptiles, fishes	—
Ammonite limestone	Shells of cephalopoda, principally ammonites	—
Coral-rag	Corals, shells, echini, ammonites	—
Bradford limestone	Crinoidea, shells, corals, cephalopoda	—
Portland oolite	Ammonites, trigoniæ, and other shells	

Strata.	Prevailing Organic Remains.	Formations.
Purbeck and Sussex marble	Fresh-water shells, and crustacea .	Wealden
Wealden limestone . .	Cyclades, and other fresh-water shells, crustacea, reptiles, fishes .	—
Tilgate grit (some beds)	Bones of reptiles, fishes, fresh-water shells	—
Faringdon gravel . .	Sponges, corals, echini, and shells	Green-sand
Jasper and chert. . .	Shells	—
Greensand	Fibrous zoophytes	—
Chalk	Polythalamia and other animalcules	Creta-ceous
Maestricht limestone	Corals, shells, ammonites, belem-nites, and other cephalopoda—	—
	reptiles	—
Hippurite limestone .	Shells, principally hippurites . .	—
Hard chalk (some beds)	Echini and belemnites	—
Flints	Sponges, & other fibrous zoophytes; Infusoria, &c. . . . . Echini, shells, corals, crinoidea . .	—
Limestone	Freshwater shells	Tertiary
Nummulite rock . .	Nummulites	—
Septaria	Nautili, turritellæ, and other shells	—
Calcaire grossier. . .	Shells and corals	—
Gypseous limestone .	Bones of mammalia, (*Palæotheria*, &c.) birds, reptiles, fishes . . .	—
Siliceous limestone . .	Shells	—
Lacustrine marl . . .	Cyprides, phryganeæ, fresh-water shells	—
Monte Bolca limestone	Fishes	—
Bone-breccia	Mammalia, and land-shells . . .	—
Sub-Himalaya sand-stone	Bones of elephants, mastodons, Reptiles, &c.	—
Tripoli	Infusoria	—
Semiopal	Infusoria	—
Richmond earth . .	Infusoria	—
Guadaloupe limestone	Human bones, land-shells, and corals	Human epoch
Bermuda limestone .	Corals, shells, serpulæ, infusoria .	—
Bermuda chalk . . .	Comminuted corals, shells, &c. .	—
Bog-iron ochre . . .	Infusoria	—

This list might be almost indefinitely extended, for I have omitted numerous strata, in which animal remains largely predominate; and in the tertiary and modern epochs, every order of animated nature is found to have contributed, more or less largely, to the sedimentary deposits; the bones of Man appearing only in the most recent accumulations; and, by the geological causes now in action, not only the remains of the existing orders of animals and vegetables, but also works of human art, are daily added to the solid crust of the globe.

46. General Inferences.—Restricting ourselves within the bounds of legitimate induction, and forbearing to speculate on those points which rest on insufficient or questionable data, we may venture to draw some general inferences as to the varying physical conditions of the surface of our planet, and of animal and vegetable life, throughout the immense periods contemplated by geology.

From the remotest epoch in the earth's history recognizable by man, to the present time, we have seen that the mechanical and chemical laws which govern inorganic matter have undergone no change. The wasting away of the solid rocks by water, and the subsequent deposition and consolidation of the detritus in strata, and their metamorphism by high temperature:—the subsidence of the dry land beneath the sea, and the elevation of areas of the ocean-bed above the waters, and the formation of new islands and continents:—the decomposition of animal and vegetable substances on the surface, and their conversion into stone or coal, under circumstances in which the gaseous principles were confined;—the transmutation of mud and sand into rock, and of earthy minerals into crystals:—these physical changes have been constantly going on, under the influence of those fixed and immutable laws, established by Divine Providence for the maintenance and renovation of the material Universe.

And although among the sentient beings which have from time to time inhabited the earth, we discover at successive periods the appearance of new forms, which flourished awhile and then passed away, while other modifications of life sprung up, and after the lapse of ages, in their turn were annihilated; yet the laws which governed their appearance and extinction, were evidently in perfect harmony with those which regulate inorganic matter. Every species was especially adapted to some peculiar state of the earth at the period of its development; and when the physical conditions changed, and were no longer favourable for the continuance of that type of organization, it became extinct. The creation of Man, and the establishment of the present order of things, which we are taught, both by Revelation and by natural records, took place but a few thousand years ago, are events beyond the speculations of Geology.

It follows from what has been advanced, that both animate and inanimate nature, linked together by indissoluble ties of mutual adaptation, have been governed by the same mechanical, chemical, and vital laws, from the earliest geological epochs to the present time; and that the absence of the fossil remains of whole orders of animals in the palæozoic ages, although, perhaps, in some measure attributable to the feeble development of those types of being, may have been occasioned by the obliteration of their remains in the rocks, from the subsequent effects of high temperature: at the same time it must be borne in mind that we are examining the beds of ancient oceans, and may not yet have explored those parts of their vast abysses in which the spoils of the land are concealed.

47. The Ancient World.—With regard to the surface of the earth in the ancient periods comprehended in our survey, there can be no doubt that its physical geography presented the same general features as in later times; and

that then, as now, the land was diversified by hills and dales, mountains and glens, volcanic peaks, elevated regions of perpetual snow, and vast areas of eternal ice,—sterile and sandy deserts, and fertile alluvial plains, irrigated by streams and rivers; the only important discrepancy being the high climatorial temperature that prevailed over extensive areas at certain epochs, and the corresponding modifications in the organic kingdoms.* But even the most remarkable anomalies in the terrestrial faunas and floras of the palæozoic ages, are not without a parallel at the present time.

Thus, New Zealand with its peculiar flora,† characterized by the predominance of ferns, club-mosses, &c. to the almost entire exclusion of the graminaceous tribes,—and its mammalian fauna, consisting of but two very small species of quadrupeds (*ante*, p. 729),—and the bones of recently extinct struthious birds,—presents a general correspondence with the lands of the Carboniferous and Triassic epochs.‡ Australia and Van Diemen's Land pos-

* See Appendix E. † See Medals of Creation, vol. i. p. 202.

‡ In a general retrospective view of this kind, the minor subdivisions or formations must, of course, be disregarded; and while on this subject, I would direct attention to the following remarks of the late President of the Geological Society, Leonard Horner, Esq., in his Anniversary Address, for 1847:—

"By whatever names we designate geological periods, there appears to exist no clearly defined boundaries between them in reference to the whole earth: such a marked line may be seen in particular localities, but every year's experience, and our more intimate acquaintance with the phenomena exhibited in different countries, and with the distribution, structure, and habits of animals and vegetables, teach us that there is a blending, a gradual and insensible passage from the lowest to the highest sedimentary strata, particularly in respect of fossil remains. The terms we employ to designate formations, can only be considered as expressing the general predominance of certain characters, to be used provisionally, as a convenient mode of classifying the facts we collect together, whilst that knowledge is accumulating which, sess a flora equally peculiar and extraordinary, and a fauna unlike that of any other part of the world, including some of the most anomalous of existing forms, as for example, that marvellous creature the Ornithorhyncus. These countries, in the abundance and variety of the Cycadeaceæ, Araucariæ, &c.—in the marsupial character of the great proportion of the mammalia,—and in the terebratulæ and trigoniæ, and the cestraciont fishes, which swarm in the seas that wash their shores, approximate in their organic relations more nearly to those ancient lands, of which the Stonesfield oolites are the debris (*ante*, p. 512), than to any of the present regions of the earth. And lastly, we have a reflected image, as it were, of the Age of Reptiles of the Secondary periods, in the exclusively reptilian character of the quadrupeds of the Galapagos Islands; one species of mouse being the only indigenous mammalian.*

"This Archipelago," observes Mr. Darwin, "is a little world within itself: most of the organic productions are aboriginal creations, found nowhere else. Seeing every height crowned with its crater, and the boundaries of most of the lava-streams still distinct, we are led to believe that within a period, geologically recent, the unbroken ocean was here spread out. Hence, both in time and space, we seem to be brought somewhat near to that great fact—that mystery of mysteries—the first appearance of new beings on this earth."

These Islands swarm with herbivorous marine reptiles, allied to the Iguanidæ, which are known in no other part

in after ages, will unravel the complicated changes that belong to the successive periods into which the history of the creation of the whole earth may be divided."

* The Galapagos Archipelago is a group of volcanic islands situated under the Equator, and between five and six hundred miles westward of the American coast. See Mr. Darwin's Journal of a Voyage round the World, chap. xvii.

of the world, and they are as completely distinct from all other existing reptiles, as are the extinct Ignanodon and Megalosaurus. The flora, too, contains more than a hundred plants unknown elsewhere. There is not a fauna or flora in any of the ancient geological periods that presents greater anomalies.*

The organic relations between the countries above mentioned and their geological analogues, may be thus expressed:—

MODERN EPOCH.	SECONDARY EPOCHS.
NEW ZEALAND .	Countries of the *Carboniferous* and *Triassic periods*, as indicated by fossil remains.
AUSTRALIA . .	The lands whence the *Stonesfield* and *Carboniferous Oolitic strata* were derived.
THE GALAPAGOS ARCHIPELAGO .	The Country of the *Iguanodon*, and the regions that supplied the detritus that formed the fluvio-marine secondary strata.

In this point of view the Country of the Iguanodon, and the Age of Reptiles, may be considered as merely disclosing exaggerated effects of the organic law, which imparted to the fauna of the Galapagos Islands its reptilian character.

If the ancient philosophers, ere the discoveries of Columbus had opened the New World to the European mind, had found in a fossil state such collocations of animals and plants as are presented by New Zealand, Australia, and the Galapagos Islands, how impossible it would have been for them, by any comparison with existing nature within their circumscribed geographical boundary, to have imagined that such assemblages of animated beings could exist contemporaneously with themselves. In fact, the present geographical distribution of animals and plants affords as many exceptions to the general rule of climatorial influence,

* See Appendix F.

in the relative number and importance of different orders of animals and vegetables, as are to be found in the vestiges of an earlier world.*

If we define those areas on a map of the globe, of which the geological structure is known from actual observation, we shall at once perceive how small a proportion of the earth's crust has been examined by the scientific observer; how large a part of the surface above the water is concealed, by perpetual ice and snow, and is otherwise inaccessible to philosophical research; and that three-fifths of the entire surface of our planet is buried beneath the waves. These facts are highly suggestive:—they teach us that notwithstanding the immense accumulation of observations made in all parts of the earth, the data hitherto obtained are insufficient to afford a true picture of the full development of organic life, as it existed in the most ancient periods.

In considering these questions, it must too be remarked, that notwithstanding the differences in the general physiognomy of the earliest and latest faunas, there are certain types common to both. Thus, though Orthoceratites, Ammonites, Lituites, &c. represent the cephalopodous mollusks in the palæozoic seas, yet these are associated with true Nautili; in like manner, with the extinct brachiopoda, the Spirifers, Leptænæ, &c. are found species of the still existing genera of Terebratula, Orthis, and Lingula. So also, in the most ancient tertiary periods, existing species of mammalia, and of terrestrial reptiles, were contemporaneously inhabitants of the land with the extinct Mastodons and other Pachyderms, and the colossal Tortoises, &c. From these considerations we may infer, that throughout all geological

* See the ingenious maps of the Geographical Distribution of existing Animals and Plants, in the delightful work of that accomplished authoress, Miss Rosina Zornlin, entitled Researches in Physical Geography, or the Earth as it is.

time, the changes on the earth's surface have been subservient to the same physical and organic laws; and that the paroxysmal terrestrial disturbances, though apparently in the earlier ages involving larger areas, and operating with greater violence, than the volcanic eruptions and earthquakes of later periods, did not affect the established order of organic life upon the surface of the globe; and we may also conclude, that throughout the innumerable ages indicated by the sedimentary formations, there was at no period a greater anomaly in the assemblages of animals and vegetables on particular regions, than exists at the present time.*

48. COROLLARY.—Thus the general result of our inquiries into the ancient condition of the earth, proves that the changes produced by mechanical, chemical, and vital agency, whether on the surface or in the interior, have been the same as at the present time, throughout all the periods revealed by Geology; and as like causes must produce like effects, will continue so long as the present material system shall endure.

Hence, deposits now in progress may subside to the innermost regions of the globe, and from exposure to intense heat, under great pressure, all traces of sedimentary origin may be obliterated; and at some future period, these metamorphosed rocks may be elevated above the surface, and appear as peaks of granite, or as primary mountain-chains, rising from beneath strata teeming with organic remains.

I cannot, therefore, concur in the generally received opinion, that in the most ancient granite accessible to human observation, we see the primeval framework of our globe—

* Hence the so-called Picturesque Sketches of Creation—the Ancient Worlds—the Vestiges of Creation—the Romance of Geology—and other works of a like nature, are in relation to the philosophy of Geology what the historical novels and romances are to History—medleys of facts and fictions.

the consolidated crust, formed on the surface of a cooling planet, and subsequently broken up by the subsidences and contractions induced by continued refrigeration. The only legitimate inference in the present state of our knowledge appears to be this,—that as at a certain depth the beds of mineral matter, whether of alluvial or of volcanic origin, may become so entirely changed in structure and composition as to afford no certain data of their original nature; therefore, for aught we know to the contrary, this world may have been teeming with life, innumerable ages ere the formation of the most ancient granitic rocks of which we can take cognizance.

49. Final Effects.—In fine, Geology does not reveal to us the first creation of animated beings; it does not afford any physical evidence of a beginning; it does not warrant the attempt to explain the miraculous interpositions of Providence by the operation of natural laws; but it unfolds to us a succession of events, each so vast as to be beyond our finite comprehension, yet the last as evidently foreseen as the first. It instructs us "*that we are placed in the middle of a scheme—not a fixed, but a progressive one,—every way incomprehensible—incomprehensible in a measure equally with respect to what has been, what now is, and what shall be hereafter.*"*

This new volume of Natural Religion which Geology has supplied, has been so ably illustrated by the Dean of Westminster,† that I need not dwell on the evident adaptation of the successive tribes of living beings through indefinite periods, to the varying physical conditions of the earth, and by which its surface was ultimately fitted for the abode of the human race. Thus the infusoria lived and died in countless myriads, and produced the tripoli and the opal; river-snails and marine mollusks secreted the marbles, and

* Bishop Butler.

† Bridgewater Treatise.

coral-polypes the limestones, with which we construct our edifices and ornament our temples and palaces; and herb, plant, and tree, have been converted either into a material to enrich the soil, or changed into a combustible mineral, to serve as a fuel in after-ages, when such a substance became indispensable to the necessities and luxuries of civilized man. Hence a new interest has been thrown around every grain of sand, and every blade of grass; and the pebble rejected by the Divine as affording no evidence of design, becomes in the hands of the Geologist a striking proof of Infinite Wisdom.*

But ought we to rest content in the assumption that all these wonderful manifestations of Creative Intelligence were solely intended to contribute to our physical necessities and gratifications?—Say, rather, that this marvellous display of beauty, power, and goodness, was designed to fill the soul with high and holy thoughts, to call forth the exercise of our intellectual powers, to excite in us those ardent and lofty aspirations after truth and knowledge, which elevate the mind above the sordid and petty concerns of life, and give us a foretaste of that high destiny, which we are permitted to hope will be our portion hereafter!

50. CONCLUDING REMARKS.—Having thus endeavoured to interpret the natural records of the earth's physical history, and traced the succession of geological epochs, each embracing indefinite periods of long duration, and the mutations in the organic kingdoms of nature coincident with the varying conditions of the lands and waters—mutations governed by laws with which we are but very imperfectly acquainted—let us finally contemplate the relations of our planet to the innumerable worlds around us. For, while

* Paley. This remark alludes to the celebrated argument of this distinguished author, on a watch and a stone, in the first page of his Treatise on Natural Theology.

Astronomy suggests that our solar system once existed as a diffused mass of vapour or nebulosity, which passing through successive phases of condensation, at length separated into a central luminary with its attendant planets and satellites (*ante*, p. 41); it also instructs us, that it is but an inconsiderable cluster of orbs in regard to the assemblage of stars to which it belongs, and of which the *Milky-way* is, as it were, a girdle, our system being placed in the outer and less stellular part of the zone.*

But the astounding thought, that all our visible Universe is but an aggregation, a single group of suns and planets, which to the inhabitants of the remote regions that can be distinguished only by our telescopes, would seem but a mere luminous spot, like one which lies near the outermost range of observation, and appears to be a fac-simile of our own, —impresses the mind with the most intense feelings of awe, of humility, and of adoration of that Supreme Being, to whom worlds, and suns, and systems, are but as the sand on the sea-shore!

——— "Awake, my soul,
And meditate the wonder! Countless suns
Blaze round thee, leading forth their countless worlds!
Worlds in whose bosoms living things rejoice,
And drink the bliss of being from the fount
Of all-pervading Love! What mind can know,
What tongue can utter all their multitudes,
Thus numberless in numberless abodes?
Known but to thee, blessed Father! Thine they are,
Thy children, and thy care—and none o'erlooked
Of Thee!"

WARE.

Again, when conducted by our investigations to the invisible Universe beneath us, the *Milky-way* and the

* See Mr. Whewell's Bridgewater Essay.

Fixed-stars of animal life, which the microscope reveals to us, we are alike overpowered by the contemplation of the minutest, as of the mightiest, of His works! And if, as an eminent philosopher has observed, our planetary system was gradually evolved from a primeval condition of matter, and contained within itself the elements of each subsequent change, still we know, that every physical phenomenon which has taken place, from first to last, has emanated from the immediate will of the Deity.

VALEDICTION.

With these remarks I take farewell of the intelligent reader, who has accompanied me through this attempt to combine a general view of geological phenomena, with a familiar exposition of the inductions by which the leading principles of the science have been established. And if I have succeeded in explaining in a satisfactory manner, how, by laborious and patient investigation, and the successful application of other branches of Natural Philosophy, the "*Wonders of Geology*" have been revealed;—if I have removed from but one intelligent mind any prejudice against scientific inquiries, which may have been excited by those who have neither the relish nor the capacity for philosophical pursuits;—if I have been so fortunate as to kindle in the hearts of others, that intense desire for the acquisition of natural knowledge, which I feel in my own, —or have illumined the mental vision with that intellectual light, which once kindled can never be extinguished, and which reveals to the soul the beauty, and wisdom, and harmony, of the works of the Eternal, I shall indeed rejoice, for then my exertions will not have been in vain.

And although my humble name may be soon forgotten, and all record of my labours be effaced, yet the influence of that knowledge, however feeble it may be, which has emanated from my researches, will endure for ever, and by conducting to new and inexhaustible fields of inquiry, prove a never-failing source of the most pure and elevated gratification.

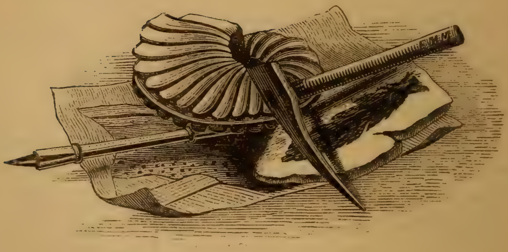
For it is the peculiar charm and privilege of Natural Philosophy, that it

——— "Can so inform
The mind that is within us—so impress
With quietness and beauty—and so feed
With lofty thoughts—that neither evil tongues,
Rash judgments, nor the sneers of selfish men,
Nor greetings where no kindness is, nor all
The dreary intercourse of common life
Can e'er prevail against us, or disturb
Our cheerful faith, that all which we behold
Is full of blessings!"

WORDSWORTH.

But transcendant as are the privileges which science confers, the true philosopher feels, with the deepest humiliation, that it is neither in the acquisition of knowledge, nor in the perception of the true and of the beautiful—even were that perceptive knowledge exalted infinitely—that human happiness can find a resting-place, or the cravings of the immortal mind be satisfied. Every step leads on the impatient inquirer to one beyond itself. "The nicest mechanical arrangement of the particles of matter, does but compel us to contemplate those subtler agents by whose action magnetic relations and chemical affinities are next developed. Exhaust their range, and still there is palpably beyond them the mystery of the vital powers. Follow that to its highest source, and yet we have but reached the first limits of those mightier energies, of reason, conscience, and volition, of which we feel within ourselves the living action. And here, where the darkness which may be felt presses most heavily upon the inquiring soul,—here in seeking to know the Cause of causes,—here alone can there be any repose for the immortal spirit. Only on HIM who made him, can Man rest at last the burden of his awful being!"*

* Bishop Wilberforce. Sermon, preached before the University of Oxford, June 27, 1847.



APPENDIX TO VOL. II.

SUPPLEMENTARY NOTES.

A. *Page* 835.—M. Strzelecki on Kirauea.—The following account of the volcanic phenomena in Hawaii is so highly interesting, that I am induced to insert it entire. "The volcano of Kirauea lies on the N.W. side of Mouna Roa, about twenty miles from the summit of that mountain, and forty from the Bay of Hilo; its latitude is 19° 27′. Its present size surpasses that of every other known volcano, yet it now hardly displays more than one-third of its original magnitude. Its crater must have once been twenty-four miles in circumference, as evidenced by the still remaining ruins of its ancient walls; the highest point of which is 5,054 feet above the level of the sea. The sunken furnace of Kirauea is now reduced to eight miles of circumference, the present crater being 4,109 feet in height above the sea; which is, therefore, at least 950 feet below the brim of the ancient crater. The edge of this precipice falls perpendicularly 600 feet lower, to the boiling surface of igneous matter. The descent to this level is often precipitous, and winds among a thousand openings, which vomit forth hot vapours, from an area thickly strewed with tabular masses of smoking lava. Like the ice in a blocked-up channel, these tabular masses remain either standing on end, or heaped in horizontal or half-raised beds, and gaping with fissures over fearful cavities, resounding with noises similar to those of a stormy sea. Six of these were in violent agitation while I was exploring the crater. The surface of the fiery matter in all of them kept at about the same height, and rose, sank, and was agitated simultaneously, which seems to show that it belonged to one mass of liquid lava, filling the whole area of the interior of the crater, and that these cavities are mere openings, and the heaps of broken lava which block up part of the crater, are a temporary crust or covering over the incandescent mass beneath. The lava of Kirauea appears to be similar to that of Hecla, which is known under the name 'cavernous;' and which, by the intensity of its heat, and the abundance of its elastic gases, produces here, as in Iceland tumefactions, varying from the thickness and delicacy of a soap-bubble, to the size of caverns twenty or thirty feet wide. These caverns, which extend in every direction, form, beneath the surface of the island, subterranean channels, through which the overflowing lava makes its way, and are often covered by a hollow arch, which yields at once to the tread. Their interior contains the most interesting incrustations of sublimed minerals, with crystalline forms, the perfection of which can hardly be appreciated without the aid of a microscope, and so delicate as scarcely to bear the breath. Mounds of sulphur, more extensive than those of Solfatara, are deposited around the southern plane of the crater.

"On the western flank of the crater above described, the appearances render it probable that the former surface of the incandescent matter was 300 feet higher up than it is at present; and that the opening of the crater of Mouna Roa, which is now 8,000 feet above, diverted the course of the intense subterranean heat from that of Kirauea, or at least diminished its intensity. It seems, also, that the incandescent matter of the interior of the crater became refrigerated and solidified in the mighty caldron; and that after a lapse of time the base on which it stood gave way, under the renewed agency of subterranean heat, when the mass cracked and slipped. A large mass of the solidified lava appears to have fallen again into the abyss, and been remolten: while a part remained lodged against the sides of the caldron, and is now seen as a rock two hundred feet high, consisting of basalt, trachyte, and lava of several varieties. *Between the scoriaceous lava approaching to slag, which lies uppermost, and the close-grained basalt which forms the lowest portion of the rock, the transition is so gradual, that it is impossible to assign the spot where basalt ceases, and lava begins.* The words, basalt, trachyte, and lava, serve, therefore, only to distinguish the upper from the lower part of a stream of molten matter."—*Strzelecki's New South Wales.*

B. *Page* 862.—Logan or rocking stones.—In that most successful of all the attempts to clothe science in the garb of fancy,—the delightful volume called "*Philosophy in Sport made Science in Earnest*,"—there is an interesting account of the *rocking-stones* of Cornwall, which the antiquaries of the last century claimed as Druidical monuments; but which have originated in the natural causes explained in the following description of the celebrated Logan or logging-stone, near the Land's End:—

"The foundation of this part of the coast of Cornwall is a stupendous group of granite rocks, which rise in pyramidal clusters to a great altitude, and overhang the sea. The celebrated Logan-stone is an immense block, weighing above sixty tons. The surface in contact with the under rock is of very small extent, and the whole mass is so nicely balanced, that, nothwithstanding its magnitude, the strength of a single man applied to its under edge is sufficient to make it oscillate. It is the nature of granite to disintegrate into rhomboidal and tabular masses, which by the further operation of air and moisture, gradually lose their solid angles, and approach the spheroidal form. The fact of the upper part of the cliff being more exposed to atmospheric agency than the parts beneath, will sufficiently explain why these rounded masses so frequently rest on blocks which still preserve the tabular form; and since such *spheroidal* blocks must obviously rest in that position in which their lesser axes are perpendicular to the horizon, it is equally evident that, whenever an adequate force is applied, they must vibrate on their point of support."—*Philosophy in Sport,* sixth edition, p. 465.

C. *Page* 874.—The Rev. J. B. Reade, F.R.S. &c. on Fossil Infusoria; in a letter to the Author.—"You are aware that a microscopic examination of recent and fossil plants has not only enabled me to establish some important facts in vegetable physiology, but has also led me to pursue an investigation intimately connected with 'the Wonders of Geology.' With respect to plants, I have already shown that the solid materials which are contained *in their ashes,* must be ranked amongst their essential elements; and that while the carbon may be readily dissipated by heat, their solid and earthy ingredients, *whether silica or lime,* so perfectly retain the form and characters of the cells and tubes into which they enter, that the burnt and unburnt specimens have sometimes been mistaken, the one for the other (*see p.* 711). I premise this remark, because it enables me to reply to your query, respecting the possibility of the existence of

Lign. 198.—Flat circular bodies in mica schist.

Corresponding in size and appearance with the rings of *Gaillonella distans;* magnified about 500 times linear.

(*By the Rev. J. B. Reade.*)

organic structure in granite, by observing, in the first place, that much of what I have stated with regard to plants, is equally applicable to large portions of the animal kingdom also, and especially to that section of it, viz. the Infusoria, which might appear, at first sight, to be wholly removed from such speculations.

"My original inquiry having thus conducted me to the conclusion, *that siliceous organization is not destructible by the agency of heat,* I thought it not unreasonable to infer that a careful and more extended microscopic examination into the condition of silica, might lead to the discovery of elementary organic forms, even in the primitive strata themselves. It was obviously not necessary to exclude granite from this examination, under the common and apparently natural impression, that the igneous fusion which preceded the present arrangement of its particles, would destroy every trace of organization; for I had before me too many manifest proofs, that an intense white heat, though capable of fusing glass, was incapable of effecting any change in the minute siliceous organization both of plants and animals. Moreover, there appeared to be a strong suspicion in some minds, that every successive surface of our globe had been characterized by its own minute living forms; and you, yourself, had more than once contended for the probability of the existence of life during the most ancient granitic period of which we are able to obtain any indications. To give a reality, however, to a *first condition,* thus pronounced to be *probable*, we must discover the skeletons of animalcules even in granite itself. But here arises a difficulty which will baffle our utmost ingenuity to remove; for, though on the one hand, I meet with siliceous corpuscles in the primitive rocks, and find, on the other hand, that the indestructible organic skeletons of recent Infusoria exhibit, even under a power of 900 linear, a striking similarity of form, yet the entire absence of external structure precludes me from assigning a common animal origin to the ancient and recent structures. Still, the inquiry, even in its present state, is far from being fruitless; for it cannot but be a matter of surprise, that immense mountain masses should have been found to consist of an aggregation of symmetrical bodies, between $\frac{1}{5,000}$ and $\frac{1}{10,000}$th of an inch in diameter, articulated together in the form of rings or of slender threads, as in limestone, and the quartz of granite: and that an exact counterpart of this curious structure in the mineral kingdom should be exhibited in the vegetable, by the mouldiness of paste, and in the animal by the *Gaillonella ferruginea*."

D. *Page* 880.—Parallel Terraces of Glen Roy.—I am induced to notice, in this place, a remarkable phenomenon observable in some of the glens of the Highlands that border the Great Caledonian Valley, because the subject has excited the attention, alike of the tourist and the geologist. In several of the glens of Lochaber, but more especially in that of Glen Roy, there are parallel terraces, at various heights, extending on either side; and which present so regular and artificial an appearance as to have been ascribed to human art; and the ancient Highlanders supposed them to be roads formed by their hero Fingal.

The valley of Glen Roy is of an oval form, and is about four miles long, and one or more wide, being bounded on two opposite sides by high mountains. Through the middle of this valley, a river, formed by the confluence of some mountain-streams, flows into the Spean water.

On each side of this long, hollow, deep valley, which is bounded by dark and lofty mountains, and at a great elevation, three strong lines are seen, parallel to each other and to the horizon; the levels of the opposite ones coinciding precisely with each other: and so striking is this symmetrical character, that the observer can with difficulty divest himself of the idea that he is contemplating some cyclopean work of the olden times. A slight examination of the nature of these parallel terraces is, however, sufficient to convince the uninstructed observer, that they are nothing more than the shores of an ancient lake, fed from the neighbouring Alpine regions, which at distant periods became shallower, and at length entirely disappeared, from the erosion of the barrier which formerly confined its waters.* The following explanation of the phenomenon is from a paper that has recently appeared; and corroborates the opinions of Professor Playfair and Dr. Macculloch: †—

The parallel shelves or terraces of Lochaber consist generally of bared rocks, forming sloping channels or water-courses; and they bear no accumulations of littoral deposits or detritus. They are perfectly horizontal, and are all coincident with some summit level, so as to admit of the water flowing over that level as over a lip. Thus the uppermost shelf of Glen Gluoy is exactly coincident with the water-shed ridge which divides that glen from Glen Roy; so that the waters which stood at that height must have flowed out at the head of Glen Gluoy into Glen Roy. In like manner the uppermost terrace in Glen Roy is coincident with the water-shed ridge dividing Glen Roy from the valley of the Spey: the waters which stood in Glen Roy, at the second level, must therefore have flowed over the head of the glen into Spey-Valley. And the middle terrace of Glen Roy coincides with a water-shed at the head of Glen Glaster. Ancient river-courses may be traced leading from the different levels of the terraces into the neighbouring glens and valleys of lower levels; and it seems evident that the waters which formed the several terraces flowed out of the glens, and descended by river-courses into the low countries. Thus the waters which formed the terrace in Glen Gluoy descended nearly thirty feet by flowing into Glen Roy; those of the upper shelf in Glen Roy flowed in like manner into the valley of the Spey; those of the middle terrace were discharged over the head of Glen Glaster down a slope of 212 feet in vertical height into Glen Spean; and the waters that produced the terrace or shelf in Glen Spean issued out of Lake Loggan by the ancient river-course at Mukkul.

It appears, therefore, that barriers originally existed, which pent up the waters at different levels in the glens, and were lowered at intervals; till at length the lakes were dried up, from the waters sinking from the level of the highest shelf to the next; and thus, by successive

* See Dr. Macculloch, On the Parallel Roads of Glen Roy, Geological Transactions, vol. iv. p. 314.

† On the Parallel Roads of Lochaber; by David Milne, Esq., Edinburgh Philosophical Journal, October 1847.

steps, as the barrier was worn away, the lowermost terrace was at length formed; and ultimately the system of lakes disappeared, from the barrier having been entirely removed.

E. *Page* 892.—SIR JOHN HERSCHEL ON THE POSSIBLE VARIABILITY OF SOLAR INFLUENCE, (*ante*, 742—745.)—Since those pages were printed, another astronomical source of periodical variability in the general temperature of the earth's surface, has been suggested by Sir John Herschel, in his magnificent recent work, entitled, *Results of Astronomical Observations made at the Cape of Good Hope.* Instances of variability in the splendour and brightness of certain stars have long been familiar to astronomers; and some remarkable phenomena of this kind were observed by Sir J. Herschel at the Cape; as, for example, in the star η *Argus,* whose light became tripled in brightness in the course of three or four weeks, and then faded to its former appearance. Considerable variability in the luminosity of some of the stars of *Ursa-Minor* has also been observed of late years. From these facts Sir J. Herschel suggests the possibility that the sun of our system may in the course of ages be subject to similar phases of augmented or diminished energy; and that such variability in the periods contemplated by Geology, may have given rise at one epoch to a general equatorial climate, and at another to one far below the general temperature that now prevails. "The grand phenomena of Geology afford, as it appears to me, the highest presumptive evidence of changes in the general climate of our globe. In the slow secular variations of our supply of light and heat from the sun, which, in the immensity of time past may have gone to any extent, and succeeded each other in any order, without violating the analogy of sidereal phenomena which we know to have taken place, we have a cause, not indeed established as a fact, but readily admissible as something beyond a bare possibility, fully adequate to the utmost requirements of geology. A change of half the magnitude in the lustre of the sun, regarded as a fixed star, spread over successive geological periods—now progressive, now receding, now stationary, according to the evidence of warmer or colder general temperatures which geological research has disclosed, or may hereafter reveal—is what no astronomer would now hesitate to admit as in itself a perfectly reasonable and not improbable supposition. Nor can it be objected that the character of a *vera causa* is wanting in such a hypothesis."

F. *Page* 894.—MR. DARWIN, ON THE GALAPAGOS ARCHIPELAGO.—"This archipelago consists of ten principal islands, of which five exceed the others in size. The largest, Albemarle Island, is of an angular form, and 100 miles in length. They are all formed of volcanic rocks; a few fragments of granite, curiously glazed and altered by heat, can scarcely be considered as an exception. Some of the craters surmounting the larger islands are of immense size, and they rise to a height of between three and four thousand feet. Their flanks are studded by innumerable smaller orifices. I scarcely hesitate to affirm, that there must be in the whole archipelago at least two thousand craters: these consist either of lava and scoriæ, or of finely-stratified sandstone-like tuff. Most of the latter are beautifully symmetrical; they owe their origin to eruptions of volcanic mud without any lava." A small jet of smoke was seen curling from one of the craters in Albemarle, and eruptions are known to have taken place in modern times.

Great parts of the surface of most of the islands are broken fields of black basaltic lava, thrown into the most rugged waves, and crossed by great fissures, and covered by stunted sun-burnt brushwood. But while the lower parts of the islands are very sterile, the upper regions, at a height of a thousand feet, possess a damp climate, and a tolerably luxuriant vegetation. The commonest bush is one of the Euphorbiaceæ, and with an Acacia, and a great odd-looking Cactus, are the only trees that afford any shade. Coarse grass and ferns abound in the upper parts, but no tree ferns, nor any of the Palm family, were observed. Large land tortoises, in prodigious numbers, are the principal animals, and form the staple article of food to the inhabitants, who are nearly all people of colour banished for political crimes from the republic of the Equator.

The rocks on the coast of Albemarle Island abound in great black lizards, between three and four feet long, belonging to two species; one of which is aquatic, and feeds on sea-weeds, the other is terrestrial. "They are allied to the Iguanidæ, (?) and belong to the genus *Amblyrhynchus,* which is confined to this Archipelago. They have long tails, flattened laterally, and all the four feet are partially webbed. Most of the other organic productions are found nowhere else: there is even a dissimilarity in those of the different islands: yet all show a marked relationship with those of America, though separated from that continent by an open space of ocean between 500 and 600 miles in width. Of terrestrial mammals, there is only one that can be considered as indigenous, namely, a mouse; and even this is confined to Chatham Island, the most easterly of the group. Of land birds, twenty-six species were obtained, 1 albut one peculiar to these islands. Of the order of reptiles, in addition to the Amblyrhynchi, there are one small species of lizard of a South American genus; one snake; and of marine turtles, or chelonia, more than one species; and two or three of tortoises. No batrachian reptiles, as frogs or toads, were observed. The Amblyrhynchi are very abundant, and the terrestrial species especially, in some places; in James's Island their burrows were so numerous, that it was difficult to find a spot free, on which to pitch a tent. The two species agree in their general structure, and in many of their habits; they have not that rapid movement so characteristic of the genera Lacerta and Iguana. They are both herbivorous, although the kind of vegetation on which they feed is very different; the land species feed on the succulent Cactus, and the aquatic species on sea-weed. Mr. Bell has given the name to the genus from the shortness of the snout: indeed the form of the mouth may almost be compared to that of the tortoise: an adaptation probably referable to their herbivorous appetites. It is very interesting thus to find a well-characterized genus, having its marine and terrestrial species, belonging to so confined a portion of the world. The aquatic species is by far the most extraordinary, because it is the only existing lizard which lives on marine vegetable productions. These islands are not so remarkable for the number of the species of reptiles, as for that of the individuals. When we remember the well-beaten paths made by the thousands of huge tortoises—the many turtles—the great warrens of the terrestrial Amblyrhynchi—and the groups of the marine species basking on the coast-rocks of every island in this archipelago—we must admit that there is no other quarter of the world where the Order of Reptiles replaces the herbivorous mammalia in so extraordinary a manner. The geologist, on hearing this, will probably refer back his mind to the Secondary epochs, when saurians, some herbivorous, some carnivorous, and of dimensions comparable only with our existing whales, swarmed on the lands and in the seas. It is, therefore, worthy his especial observation, that this archipelago, instead of possessing a humid climate and rank vegetation, cannot be considered otherwise than extremely arid, and, for an equatorial climate, remarkably temperate. The botany is as peculiar as the zoology. Of flowering plants, 185 species were collected, of which 100 are new; that is, previously unknown to the botanist: and 40 cryptogamic species." Notwithstanding the length of this extract, the reader should refer to the original for many highly interesting particulars, and sagacious comments, which are here necessarily omitted.—*Mr. Darwin's Journal of a Voyage Round the World,* chap. xvii.

DESCRIPTION OF THE PLATES

OF

VOLUME II.

DESCRIPTION OF PLATE V.

LIVING ZOOPHYTES; Lecture VI.

Fig. 1. *Sertularia setacea;* a branch with three polypes expanded; highly magnified; p. 615.

2. *Campanularia gelatinosa;* a branch highly magnified; some of the polypes are protruded, and others within their cells; p. 616.
3. *Gorgonia patula;* magnified view of a branch, with six polypes expanded; p. 617.
4. The coral of *Caryophyllia fasciculata;* p. 623.
5. *Flustra pilosa*, encircling a piece of fucus; natural size; p. 606.
6. A single cell of *Flustra pilosa*, with the polype protruding its tentacula; p. 605.
7. A single cell of a Flustra, with the included polype; p. 605.
8. A small portion of a Flustra magnified to show the form and arrangement of the cells; p. 605.
9. *Corallium rubrum*, or red coral; a branch with its fleshy investment, and several polypes in different states of expansion, as they appear when alive in the sea; p. 618.
10. *Alcyonium gelatinosum;* a portion highly magnified; some of the polypes are expanded, and others in various states of contraction. The substance so commonly attached to shells and stones on our sea-coasts, and known by the name of *Dead-men's fingers*, is a compound zoophyte of this kind, and is termed *Alcyonium digitatum*. (See Dr. Johnston's British Zoophytes, pl. 26.)
11. *Pocillopora cerulea*, from the Indian seas; drawn when alive in the water; p. 623.

Plate V.

J. Dinkel del.

Hullmandel & Walton Lithographers.

LIVING ZOOPHYTES.

DESCRIPTION OF PLATE VI.

LIVING ZOOPHYTES; Lecture VI.

Fig. 1. *Pavonia lactuca;* a group of four cells, each cell containing a beautiful green polype; from the shores of the South Sea Islands; p. 624.
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3. Branch of a *Gorgonia*, from the Mediterranean; p. 617.
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5. *Madrepora plantaginea*, with the polypes expanded; p. 621.
6. The disk of the polype represented in *fig.* 4, when fully expanded.
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9. *Sarcinula musicalis*, or organ-pipe coral; from the shores of New South Wales, as it appears in the water, with its beautiful green polypes protruded; p. 619.
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11. A group of living *Actinia*, or Sea animal-flowers; p. 621.
12. A polype of a Tubipore expanded; highly magnified; p. 620.
13. *Astræa viridis*, represented as alive in the sea; some of the polypes are expanded, and others contracted; p. 623.
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Plate VI

J. Dinkel lith. Hullmandel & Walton Lithographers

LIVING ZOOPHYTES

GLOSSARY.

*** *Explanations of most of the scientific terms not included in this Glossary, are given in the text, and may be found by consulting the Index.*

ACEPHALA	molluscous animals without a head, as the Oyster, &c.
ACICULAR	needle-like, sharp-pointed.
AEROLITES	mineral masses that fall from the atmosphere.
ALGÆ	a family of marine plants.
ALLUVIUM	water-worn materials.
ALUMINOUS	clayey.
ALUMINUM	metallic base of clay.
ALVEOLA	sockets of the teeth.
AMORPHOUS	shapeless; devoid of regular form.
AMYGDALOID	cellular volcanic rocks, the cavities of which are filled with other substances.
ANASTOMOSED	branching and interlacing.
ANCHYLOSED	joints of bones immoveably united.
ANNELIDES	animals having an external integument formed of rings; as the Worm.
ANTENNÆ	the feelers of insects.
ANTHOZOA	animal flowers, as the Actinia.
ANTHRACITE	stone, or cannel coal, or culm.
ANTHRACOTHERIUM	an extinct animal, allied to the palæotheria, found in anthracite.
APTERYX	destitute of wings; applied to a particular genus of bird.
ARBORESCENT	tree-like.
ARENACEOUS	sandy.
ARGILLACEOUS	composed of clay.
ARTICULATA	animals without an internal skeleton, and having jointed coverings, as Insects.
ARUNDINACEOUS	(*arundo*, a reed); plants of the reed tribe.
ASCIDIAN	shell-less mollusks, shaped like a bottle.
ASTRÆA	a genus of corals.
AUGITE	a dark-green mineral found in many volcanic rocks.
AULOLEPIS	*pipe-scale* fish.
BARYTES	heavy spar; a mineral so called.
BASALT, OR TRAP	ancient lava, composed of augite and felspar; often columnar.
BASIN	a series of deposits formed in a depression of older rocks.
BATRACHIAN	animals analogous in structure to the frog; as the Salamander.
BELEMNITE	(from *belemnon*, a dart,) fossil dorsal bone of an extinct genus of cuttle-fish.

BIFID .... divided in two parts, or forked.
BILOBED .... divided into two lobes.
BITUMEN .... mineral pitch or tar.
BRACHIAL .... belonging to the arm.
BRACHIOPODA .... molluscous animals that move by arm-like processes.
BRANCHIA .... aquatic organs of respiration, as gills.
BRECCIA .... conglomerate of fragments of rocks.
BRYOZOA.................. *moss-animals;* polypes that encrust other bodies, as the *Flustræ.*

CALC SINTER........... deposition from thermal springs charged with carbonate of lime.
CALCAIRE GROSSIER. a tertiary limestone of the Paris basin.
CALCAREOUS .... composed of lime.
CALCIUM.................. metallic base of lime.
CAMPANULARIÆ ...... arborescent corals, with bell-shaped cells.
CANCELLATED .... the cellular structure of a bone.
CAPSULE .... (*socket;*) the hollow or concavity of a bone which receives the head of another bone.
CARBON .... the elementary substance of charcoal and the diamond.
CARBONATE OF LIME . lime and carbonic acid.
CARBONIFEROUS ...... belonging to coal.
CARNEOUS .... fleshy.
CARYOPHYLLIA......... branched stellular coral.
CAUDAL .... belonging to the tail.
CENTRIFUGAL .... a force directed from the centre to the circumference.
CEPHALIC .... belonging to the head.
CEPHALOPODA .... animals having the instruments of motion placed around the head; as the Cuttle-fish.
CERVICAL .... belonging to the neck.
CETACEA.................. marine mammalia, as the Whale, Porpoise, &c.
CHALCEDONY .... a species of silex, named from Chalcedon, a city of Asia, near which it is found in great abundance.
CHELÆ..................... claws.
CHELONIA .... animals of the turtle tribe.
CHERT .... a siliceous mineral allied to flint and chalcedony.
CHOANITE .... a zoophyte of the chalk.
CILIA .... hair-like vibratory organs.
CIRRI .... curled processes, as in the Barnacle.
CLAVATED .... club-shaped.
CLEAVAGE .... a peculiar laminated structure in slate rocks.
COLEOPTERA .... insects having wing-cases, as Beetles.
CONCHOIDAL .... shelly.
CONCRETION .... a coalition of separate particles.
CONDYLE .... an articulating surface or joint.
CONFORMABLE .... applied to parallel strata lying upon each other.
CONGLOMERATE .... pebbles or waterworn fragments cemented together, as in Puddingstone.
CONIFERÆ .... trees bearing cones, as the Fir, Pine, &c.
CORDIFORM .... heart-shaped.
CORNBRASH .... a coarse shelly limestone of the oolite.
CORTICIFEROUS .... belonging to the bark of a tree.
COTYLEDONS .... seed-lobes of plants.
CRAG .... a term applied in Suffolk to certain tertiary beds of sand and shells.
CRATER .... the vent of a volcano.
CRATERIFORM .... having the form of a crater.
CRENULATED............ knotched, or toothed.
CRETACEOUS .... belonging to chalk.
CRINOIDEA............... lily-shaped animals.
CROP OUT .... signifying the emergence of a stratum on the surface.
CRUCIAL .... in form of a cross.

CRUSTACEA .... animals having an external crust or skeleton, as the Crab.
CRYPTOGAMIA .... plants with concealed fructification, as Mosses, Ferns, &c.
CRYSTALLINE .... presenting the structure of crystals.
CRYSTALS .... symmetrical forms assumed by mineral substances.
CUPREOUS .... coppery.
CYATHIFORM .... cup-shaped.
CYCADEÆ .... plants allied to the palms and ferns.

DEBRIS .... the ruins or detritus of rocks and strata.
DECIDUOUS .... parts which are shed, as leaves of trees.
DELTA .... alluvial deposits formed by rivers.
DENDRITIC............... branched like a tree
DENUDATION .... the removal of strata by the action of water, so as to expose the rocks beneath, as in the Wealden of the S.E. of England.
DERMAL .... belonging to the skin.
DESICCATION .... the act of drying.
DETRITUS .... disintegrated materials of rocks.
DICOTYLEDONOUS...... plants with seeds having two lobes.
DIDELPHIS............... a marsupial animal, allied to the opossum.
DILUVIUM .... a term formerly employed to designate ancient alluvial deposits.
DIP .... the inclination of strata.
DIPTERA .... insects having two wings.
DISCOIDAL .... in the form of a disk.
DIKE .... an intrusion of melted matter into rents or fissures of rocks.
DOLOMITE .... crystalline magnesian limestone.
DRUSES.................... minute crystals lining the cavities of minerals; as, for example, *drusy quartz* in the hollows of flint nodules.

EARTH'S CRUST .... that portion of the solid surface of the earth which is accessible to human observation.
ECHINODERMS .... animals having a prickly external integument, as the Star-fish, Sea-Urchin, &c.
ECHINUS .... sea-urchin.
EDENTULOUS .... *toothless;* animals having no front teeth, as the Armadillo.
ELYTRA .... wing-cases of insects.
ENCRINITE .... a genus of lily-shaped animals.
ENTOMOSTRACA .... shelled crustaceans, as the Cyprides.
EOCENE .... the dawn of the present epoch; the early tertiary strata.
EPHEMERON .... the creature of a day.
ERODED .... worn away.
ESCARPMENT............ the steepest side of a hill or mountain-chain.
EXUVIÆ.................... fossil remains of animals.

FAULT .... interruption of the continuity of strata with displacement.
FALUN .... a French term for tertiary strata analogous to the Crag.
FAUNA .... the zoology of a particular country.
FELSPAR.................... a mineral which enters into the composition of many primary rocks.
FELSPATHIC .... belonging to, or composed of felspar.
FERRUGINOUS........... impregnated with iron.
FLORA....................... the botany of a particular country.
FOLIACEOUS............. arranged like leaves.
FORAMINIFERA .... a division of animalcules having perforated shells.
FORMATION .... a group, or series of strata, supposed to have been formed during one geological epoch.
FOSSILIFEROUS......... strata containing fossils.
FUSIFORM................. spindle-shaped.

GASTEROPODA .... mollusks with the locomotive organs on the underpart of the body, as the Snail.
GELATINOUS .... jelly-like.
GLOBOSE .... globe-like.
GORGONIA .... a genus of flexible arborescent corals.

GRALLÆ.................... (*Stilts;*) applied to birds having feet like the heron.
GRANULES................ little grains.
GRAMINEÆ .... the order of plants comprising the grasses.
GREENSAND.............. the lowermost member of the chalk formation.
GREENSTONE............ an ancient volcanic rock.
GREYWACKÉ .... rocks of a conglomeritic character, indurated by heat.
GRIT .... granular calciferous sandstone.
GYPSUM .... sulphate of lime.

HEMIPTERA .... insects with wings, half horny, and half membraneous.
HERBIVOROUS .... living on herbs.
HOLOPTYCHIUS......... allwrinkle fish, in allusion to the corrugated scales.
HOMALONOTUS.......... (*smooth-backed;*) name applied to a genus of trilobites, in which the lobes are but feebly produced.
HOMOLOGUE .... the analogous organ in different animals.
HYALINE .... crystalline appearance, or pellucid.
HYDRA...................... freshwater polype.
HYDROZOA .... coral-polypes organized like the Hydra.
HYMENOPTERA .... insects with four membranous wings.
HYPOGENE .... rocks formed in the interior of the earth, as Granite.

ICEBERGS .... floating masses of ice.
IGUANA .... a lizard of the West Indies.
IMBRICATED .... laid over each other like scales.[7]
INCANDESCENT .... applied to mineral masses in a state of intense fusion.
INDUCTION .... the derivation of principles from facts.
INFUSORIA .... microscopic animals that abound in infusions.
INSECTIVOROUS......... animals that live on insects, as the Hedgehog.
INSPISSATED............. dried up.
INVERTEBRATA .... animals without a bony, flexible spine, or vertebræ, as worms, lobsters, &c.

LACUSTRINE............. belonging to a lake.
LAMELLATED .... covered with thin plates or scales.
LAMELLIFORM .... shaped like a thin plate or scale.
LAMINÆ .... the thin layers of which a stratum is composed.
LAPILLI.................... volcanic ashes, in which globular concretions prevail.
LARVA .... the first stage of an insect.
LAVA .... melted mineral matter erupted from volcanoes.
LEPIDOPTERA........... insects having scaly wings, as Moths.
LIAS .... a provincial term, applied to a group of strata situated between the oolite and the new red sandstone.
LIGNITE .... carbonized wood.
LITHODOMI .... mollusca which perforate stones, shells, &c.
LITHOLOGICAL.......... the stony character of a mineral mass.
LITHOPHYTES .... stone-plants; a term applied to corals.
LITTORAL .... belonging to the sea-shore.
LOESS .... a tertiary deposit on the banks of the Rhine.
LYCOPODIACEÆ......... the family of club-mosses.

MACROURA............... long-tail, applied to crustaceans, as the Lobster.
MACROPOMA .... *long operculum*, name of a sauroid fish.
MAMMALIA, or MAMMIFERS .... animals which give suck to their young.
MAMMILLATED......... studded with mammillæ, or rounded protuberances.
MANDIBLES............... jaws.
MANTLE.................... the soft external envelope of the mollusks.
MARL .... a mixture of lime and clay.
MARSUPIAL .... animals which carry their young in a pouch, as the Kangaroo.
MATRIX .... the substance in which a fossil is imbedded.
MEDULLARY .... a term applied to the central pith in plants, and to the matter of the brain and spinal marrow in animals.

METAMORPHISM, or METAMORPHOSIS ... the change induced in strata by exposure to a high temperature.
MICA ... a simple mineral, one of the component parts of granite.
MICACEOUS... containing mica.
MIOCENE... middle tertiary series.
MOLARES ... grinding teeth.
MOLECULES ... microscopic particles.
MOLLUSCA ... soft animals, destitute of a bony structure, as Shell-fish.
MONADS ... the minutest infusorial animalcules.
MONITOR ... a genus of lizards inhabiting the tropics.
MONOCOTYLEDONOUS.. plants having seeds with but one lobe, as *Wheat*.
MORAINE ... an accumulation of debris formed in valleys by glaciers.
MULTILOCULAR... many-chambered shells, as the Nautilus.
MULTIVALVE ... shells composed of many pieces, as the Chiton.
MUSCHELKALK ... a shelly limestone of the Triassic system.

NACREOUS ... pearly.
NEUROPTERA... insects having wings finely nerved, as the Dragon-fly.
NODULE ... a rounded mineral mass, as a chalk-flint.
NORMAL ... natural, or original condition.
NUCLEUS ... a kernel, or point round which other materials collect.

OBSIDIAN ... glassy lava.
OCCIPUT ... the back part of the skull.
OOLITE ... limestone composed of an aggregation of spheroidal particles.
OPERCULUM ... *a lid;* applied to the gill-covering in fishes, and the plat that closes the aperture in univalve shells.
OPHIDIANS ... the snake tribes.
ORNITHORHYNCHUS... a genus of animals having the mouth produced into a beak like a bird.
OSSICULA ... small bones.
OVATE ... egg-shaped.
OVIPAROUS ... animals which bring forth eggs.
OUTLIER ... a detached or isolated mass of strata.
OXIDE ... the combination of oxygen with any metallic substance.

PACHYDERMATA ... thick-skinned animals, as the rhinoceros, elephant, &c.
PALÆONTOLOGY ... the science which treats of extinct animals and vegetables.
PARIETES ... the walls of the cavities in animals.
PECTINATED ... toothed like a comb.
PEDIFORM ... shaped like a foot.
PEDUNCLE ... a stalk, or support.
PELAGIC or PELAGIAN. belonging to deep seas.
PEPERINO ... a volcanic conglomerate.
PETROLEUM ... mineral oil.
PINNATE ... shaped like a feather or fin.
PISOLITIC ... pea-like; resembling peas, agglutinated together.
PLEXUS ... a bundle of vessels.
PLIOCENE ... the newer groups of the tertiary formations.
PLUMOSE ... feather-like.
POLYPARIA... corals.
PORPHYRY ... an ancient igneous rock.
POZZUOLANA ... volcanic ashes.
PRECIPITATE... the chemical separation, and deposit in a solid form, of a substance held in solution by water.
PTYCHODUS ... *wrinkle-tooth* fish.
PUMICE ... light, spongy or porous lava.
PYRIFORM ... pear-shaped.
PYRITES ... sulphuret of iron.
PYROGENOUS ... igneous, applied to ancient melted rocks.

Quadrumana .... (*four-handed*); the monkey tribes.
Qua-qua-versal...... applied to concentric strata, that dip on every side.
Quartz .... a mineral composed of pure flint.
Quartzose .... rocks composed of silex, or flint.

Radiata .... the lowest primary division of the animal kingdom: as, the Echinoderms, Polyparia, &c.
Ramose .... branched.
Reniform................ kidney-shaped.
Reticulated .... resembling net-work.
Rodentia .... (*gnawers*); an order of animals having teeth of a peculiar structure, by which they can drill holes, as the Rat, Squirrel, &c.
Rubble .... fragmentary beds of stone.
Ruminantia .... animals that chew the cud, as the Deer, Ox, &c.

Saurians .... reptiles of the lizard order.
Scaphite .... extinct genus of cephalopoda, of a boat-like form.
Scoriæ .... volcanic cinders.
Sedimentary .... deposited as a sediment by water.
Segregation........... a chemical separation of mineral substances.
Septa....................... partitions, as in the shells of the Nautili.
Septaria .... nodules of clay, having crevices filled with spar.
Serrated .... toothed like a saw.
Sertularia .... a genus of arborescent corals.
Shale, or Schist...... slaty clay.
Silex .... flint.
Silicon .... the base of flint.
Siliceous .... flinty.
Silicified .... changed into flint.
Silt .... fluviatile mud.
Sinter .... a precipitate from mineral springs.
Spatangus .... a genus of sea-urchins.
Spathose .... opaque.
Spheroidal .... oblate, or having the form of a spheroid.
Spicula .... sharp-pointed processes.
Squamous .... arranged like scales.
Stalactite .... pendent masses of carbonate of lime.
Stalagmite .... calcareous concretions formed on the floor of caves by droppings from the roof.
Stellular .... having star-like forms.
Sternal .... relating to the sternum or chest.
Sternum .... the breast-bone.
Stratified .... deposited in layers.
Stratum .... a layer of any deposit.
Strike .... the direction or line of bearing of strata, which is always a right angles with the dip.
Stufas .... volcanic vents emitting gases and vapours.
Syenite, or Sienite . a species of granite in which *hornblende* supplies the place of *mica*.

Tentacula .... feelers.
Tertiary................. ancient formations, but newer than the chalk.
Testacea .... shells.
Thermal .... hot.
Thoracic................. belonging to the chest or thorax.
Trachyte .... lava chiefly composed of felspar.
Trap rocks............. ancient volcanic rocks; the term derived from the Swedish, *trappa*, a stair.
Travertine............ crystalline tufaceous limestone.
Tricuspid .... having three points.
Tridactyle .... three-fingered.
Trilobate .... three-lobed.

TRILOBITES .... an extinct family of crustacea, the body divided into three lobes.
TUBIPORA .... organ-pipe coral; corals composed of tubes.
TUFA .... calcareous deposit from incrusting streams.
TUFF .... earthy volcanic rock.
TURBINATED .... top-shaped, in form of an inverted cone.

UNCONFORMABLE ..... strata lying in a different position to those on which they rest.
UNGULATA .... hoofed animals.
UNIVALVE .... shell composed of but one piece.

VEINS .... fissures in rocks, filled up by mineral substances.
VERMES .... worms.
VERMIFORM .... worm-shaped.
VERTEBRATED .... animals having a flexible, osseous, spinal column.
VERTICILLATE .... arranged in whorls.
VESICULAR................ full of vesicles or cells.
VILLI .... processes in animal structures, resembling the pile of velvet.
VITRIFICATION......... the fusion of a substance into glass by heat.
VIVIPAROUS .... bringing forth live young.

ZEOLITE . ... peculiar minerals found in volcanic rocks.
ZOOLOGY .... the study of animals.
ZOOLOGICAL .... relating to animals.
ZOOPHYTES............... animal-plants, a term applied to corals and other animals that resemble vegetables in form.

CORRIGENDA.—VOL. I.

Page 6, line 5 from the bottom:—*for* Coals *read* Coal.
— 52, — 10 ———————— Obers — Olbers.
— 134, — 5 ———————— presented by — of.
— 207, — 7 ———————— Cambrian — Cumbrian.
— 208, — the top line———— Cambrian — Cumbrian.
— 223, — 16 from the bottom:—*dele* and Norfolk.
— 224, — 21 ———————— or Norfolk.
— 252, — 9 from the top; *for* have been already, *read* will be hereafter (*see* pp. 260 and 265).
— 288, is misprinted 828.
— 357, line 19 from the bottom; *for* Odontapsis, *read* Odontaspis.
— 400, foot note†; *for* Inglesi, *read* Jugleri.
— 412, line 3 from the bottom; *insert a semicolon after* tertiary.
— 464, line 11, from the top, *dele semicolon, and insert a* comma.
— — — 23, ———— *dele the semicolon after* diallage rock.
— — — 31, ———— *for* alteration, *read* alterations.

VOL. II.

Page 533, line 7 from the top; *for* Rhyncosaurus *read* Rhynchosaurus.
— 552, 553, and 559, the same misprint occurs.
— 586, line 7 from the bottom, *dele* utterly.
— 607, — 7 from the top; *for* bu, *read* but.
— 622, — 15 ———— *for* ruber, *read* rubra.
— 691, — 3 from the bottom, *dele*, the: *read* For the most bituminous coal, &c.
— 694, — 13 from the top; *for* remarked *read* described.
— 699, — 22 ———— *for* living *read* recent.
— 701, — 14 from the bottom; *for* is as low, *read* is a slow.
— 750, — 4 from the top; *dele the comma after* fed.
— 792, — 9 ———— *for* Mr. *read* M.
— 797, — 16 ———— *for* orgauic, *read* organic.
— 841, bottom line; *for* mus *read* must.
— 846, line 9 from the bottom: *dele* mode of.
— 895, — 8 from the top; *dele the comma after* concealed.
— —, — 11 ———— *for* is *read* are.
— 907, — 8 ———— *for* uninstructed *read* instructed.
— 909, — 27 ———— *dele the* (?).

*** As some of these errata affect the meaning, the reader is requested to correct them with a pen or pencil, before perusing the work.

DIRECTIONS TO THE BINDER.

*** The Engraving of the Country of the Iguanodon is to front the Title-Page of Vol. I.

The Geological Map of England, *Plate* I. to be placed opposite to p. 464, Vol. I.

Plates II. III. and IV. to face their respective description in Vol. I.; Plates V. and VI. to be placed at the end of Vol. II., opposite to p. 912 and p. 914.

ADDENDA.

Elevation of the Land.—From the following statement it appears, that the slow upward movement of the land is in progress in other countries as well as in Scandinavia (*ante*, p. 116).

"*Gradual rising of Newfoundland above the sea.*—The whole of the land in and about the neighbourhood of Conception Bay, very probably the whole island, is rising out of the ocean at a rate which promises, at no distant day, materially to affect, if not to render useless, many of the best harbours on the coast. At Port de Grave a series of observations have been made, which undeniably prove the rapid displacement of the sea-level in the vicinity. Several large flat rocks over which schooners might pass some thirty or forty years ago with the greatest facility, are now approaching the surface, the waters being scarcely navigable for a skiff. At a place called the Cosh, at the head of Bay Roberts, upwards of a mile from the sea-shore, and at several feet above its level, covered with five or six feet of vegetable mould, there is a perfect beach, the stones being rounded, of a moderate size, and in all respects similar to those now found in the adjacent land washes."—*Newfoundland Times*, October, 1847.

Discovery of the Eggs of the Moa of New Zealand,—(see *ante*, p. 129).—My son, Mr. Walter Mantell, of Wellington, in a late exploring expedition into the interior of the country, in search of remains of the gigantic struthious birds with which those islands once abounded, discovered numerous fragments of the eggs, some of which I have received. These specimens consist of small portions, having their edges rounded, as if waterworn. The shell is of a light cream colour, and the external surface is marked with numerous fine, short, interrupted, linear grooves: differing from the eggs of the Ostrich and Emu, but most nearly resembling those of the latter. The shell is relatively thin, and from the slight degree of convexity of the largest specimen, must have been of great size.

The bones collected by my son amount to upwards of 700, belonging to various parts of the skeleton, and to several species of Moa. He informs me, that among them are portions of skulls and mandibles: the latter will be a highly interesting addition to our knowledge of the osteology of these colossal bipeds, for no vestiges of these bones have been sent to England. The specimens were shipped to Sydney in April last, but have not yet arrived.

My son could obtain no further information from the natives, as to the probability that any species of these struthious birds, except the Apteryx (*ante,* p. 128), are still in existence. From the fresh appearance of many of the bones and egg-shells, it is however evident, that this noble race of birds inhabited New Zealand at no very remote period.

Fossil Beaver (see *ante,* p. 154).—Some bones, teeth, and a skull with the lower jaw, of a gigantic beaver, have recently been found in North America, in the alluvium that contains the remains of the Mastodons. It appears to be nearly allied to the *Trogontherium,* found in the mammoth deposits of Siberia. The original is estimated at twice the size of the common Castor, or five feet in length. An interesting memoir of these fossils, with admirable lithographs, is published in the Boston Journal of Natural History for 1846; by Dr. Jefferies Wyman.

Skull of the Zeuglodon (see *ante,* p. 281).—A skull of this extinct cetaceous animal of the eocene strata of North America, has recently been discovered near Charleston, and is described in the American Journal of Science for *September,* 1847. The occiput, with its double condyle, is preserved. It belonged to a very young animal, the entire length being only fifteen inches. The correctness of Professor Owen's determination of the natural affinities of the Zeuglodon, is thus placed beyond all doubt.

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TO THE FORMER EDITIONS OF THE

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*** The references to Mr. Lyell's Principles of Geology are to the 6th edition of that work.

The numerous references to the Medals of Creation were made to economize space, by avoiding the necessity of inserting the authorities therein quoted.

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THE END.

R. CLAY, PRINTER, BREAD STREET HILL.