THE

WONDERS OF GEOLOGY;

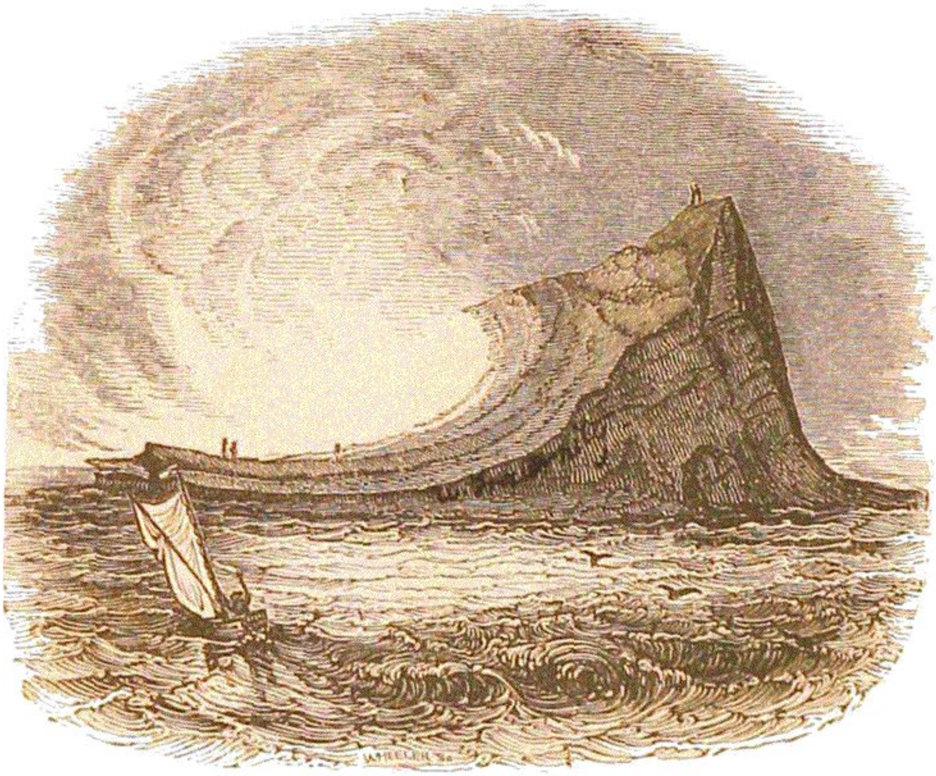
BY

GIDEON ALGERNON MANTELL, LL.D. F.R.S.

AUTHOR OF

THE GEOLOGY OF THE SOUTH EAST OF ENGLAND,

ETC. ETC.



Volcanic Island in the Mediterranean.—Page 732.

" To the natural philosopher there is no natural object unimportant or trifling: from the least of nature's works he may learn the greatest lessons."—SIR J. F. W. HERSCHEL.

" We know not a millionth part of the wonders of this beautiful world."—*LEIGH HUNT.*

IN TWO VOLUMES.

VOL. II.

THIRD EDITION.

LONDON:—RELFE AND FLETCHER, 17, CORNHILL.

1839.

THE

WONDERS OF GEOLOGY;

OR,

A FAMILIAR EXPOSITION

OF

GEOLOGICAL PHENOMENA;

BEING THE SUBSTANCE OF A COURSE OF LECTURES
DELIVERED AT BRIGHTON.

BY

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OF THE PHILOSOPHICAL INSTITUTION OF BOSTON;
OF THE HISTORICAL SOCIETY OF QUEBEC; AND OF THE PHILOSOPHICAL
SOCIETIES OF YORK, NEWCASTLE, ETC.

"Horum contemplatio multiplicem habet usum. Sunt instar nummorum memorialium, quæ de preteritis globi nostri fatis testantur, ubi omnia silent monumenta historica."—BERGMAN. *Med. de Syst. Foss.*

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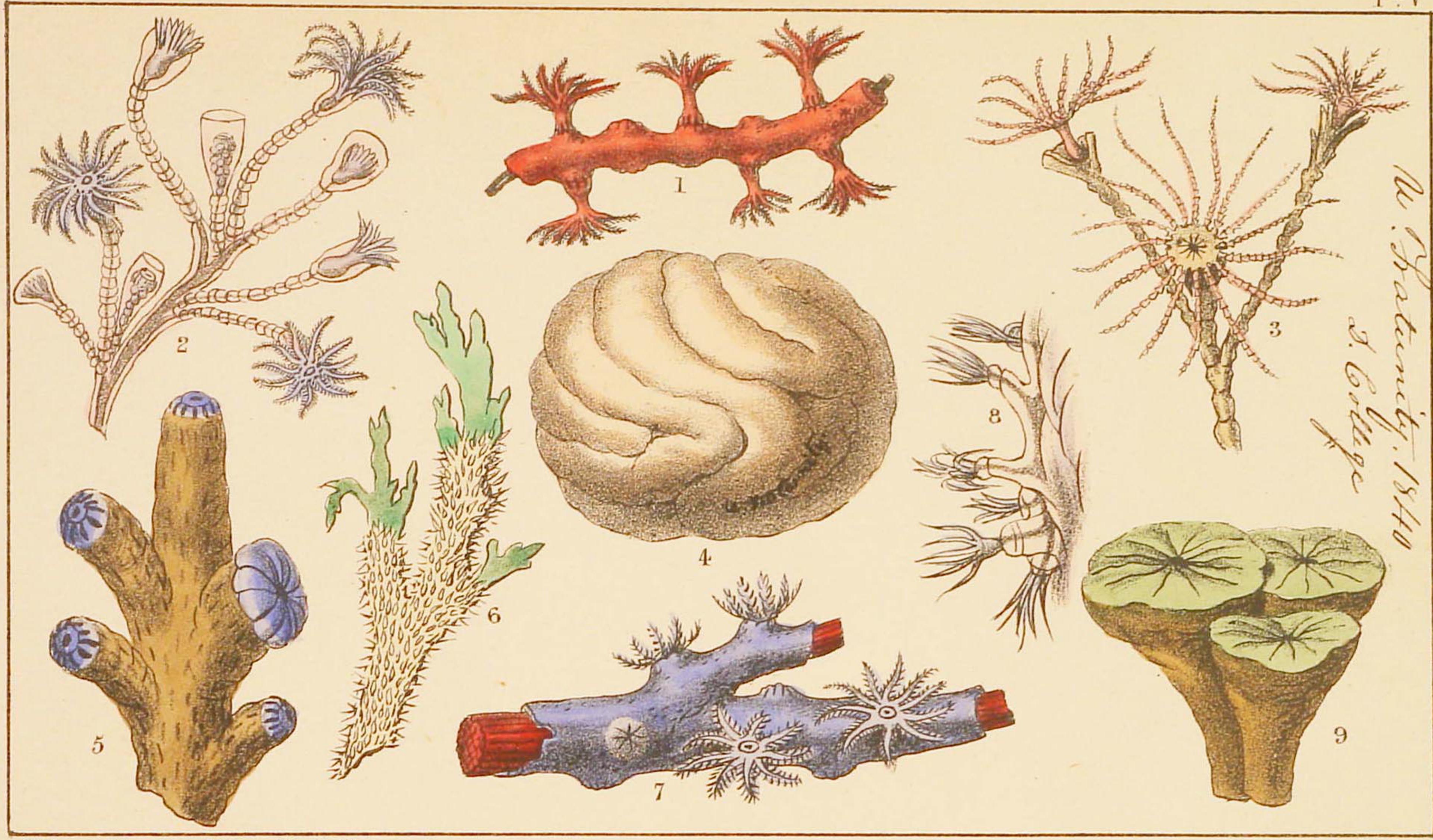
Pl. V



Ellen Maria Mantell del.t

G. Scharf Lithog:

ZOOPHYTES.

DESCRIPTION OF PLATE V.—*Frontispiece to Vol. II.*

Fig.

1. *Gorgonia patula;* magnified view of a branch, with six polypes expanded; p. 537.
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1. THE ZOOLOGICAL CHARACTER OF THE CHALK. —The examination of the chalk and wealden has afforded a striking illustration, 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 epoch which comprises the secondary formations. It will therefore be interesting in this stage of our inquiry to note the development of animal life during that period.

The ocean of the chalk appears to have possessed the principal existing marine types of organization; it teemed with many species of dog-fish, lamna, galeus, and other genera of the shark family—with fishes related to the chimera, salmon, smelt, pike, dory, and ray, together with many of genera now extinct. Nautili and other cephalopoda abounded, as in our tropical seas; and the family of echinodermata, or sea-urchins, was profusely developed: star-fish, encrinites, and other radiaria; crustacea allied to the crab, lobster, shrimp, and prawn; univalve and bivalve mollusca; all these leading divisions of marine existence inhabited its waters. And although we have proof that numerous genera now no more, together with others of excessive rarity in the present seas, then swarmed in prodigious numbers; and negative evidence that the cetacea, as the whale, porpoise, seal, &c. were not among its inhabitants; yet the varied forms of animal life whose presence in the ocean of the chalk is attested by their fossil remains, unquestionably establish that the sea presented the same general conditions, and bore the same relation with the atmosphere and with light, as at the present time. The most remarkable peculiarity in the zoological character of the chalk is presented in the class of reptiles. With the exception of a lizard belonging to the family of the *Iguanidæ*, which inhabits the sea off the coast of South America, turtles are the only known living marine reptiles;

but the chalk ocean was not only peopled by *chelonia,* but also by two or more enormous saurians, for the mosæsaurus lived in the cretaceous seas; and the ichthyosaurus, and plesiosaurus, as will be shown hereafter, were unquestionably inhabitants of the deep.

2. Zoological character of the wealden.—During the wealden epoch the lakes and rivers were peopled by fishes, mollusca, and crustacea, which, though specifically distinct from the recent, presented the same principal types as now exist in fresh-water. The lacustrine and marsh plants, and the palms, tree-ferns, and cycadeæ, constitute a flora offering peculiar generic and specific characters, but resembling the usual forms of tropical vegetation. The fresh-water turtles, crocodiles, and wading-birds, are in accordance with the fauna of modern tropical regions; but the colossal reptiles,—the iguanodon, megalosaurus, and hylæosaurus,—whose living analogues must be sought in the pigmy iguanas and monitors, constitute a zoological character altogether at variance with the existing economy of animated nature. Here, then, we have evidence of a country *almost exclusively inhabited by enormous reptiles;* for although the most delicate plants, leaves, and fruits, the fragile bones of birds, the epidermis, and even ligaments of brittle shells, are found, not a vestige of any mammiferous animal has been discovered. I forbear to comment in this place on this astounding fact, of which the

tertiary deposits afforded us no intimation. We have now approached the *Age of reptiles*—that geological epoch in which the earth swarmed with enormous oviparous quadrupeds; and the sea, the lakes, and the rivers teemed with reptile forms.

3. SITE OF THE COUNTRY OF THE IGUANODON.—Before I proceed to the consideration of the secondary formations which are antecedent to the wealden, I would briefly consider the question relative to a difference of climate which our discoveries seem to imply. From what has been advanced it is natural to inquire, whether at the period of the wealden these latitudes enjoyed a tropical temperature—whether turtles, crocodiles, and gigantic reptiles, here flourished amid forests of tree-ferns and palms; or if the geographical situation of the country of the iguanodon was far distant from the area now occupied by its spoils? I shall not venture to give a decided reply to this interrogation, but content myself with offering some remarks on the appearance of transport which the fossils of the wealden exhibit; for I may premise, that the state of the organic remains does not seem to warrant the assumption that the reptiles and terrestrial plants, like the zoophytes, mollusca, and fishes of the chalk, lived and died on the spots where their remains are found entombed. With the exception of the beds of river shells, of cyprides, and of equiseta, (which naturally affect a marshy soil,) all the remains bear marks of having been

transported by water from a distance. For although three-fourths of the bones are more or less broken and rolled—the teeth detached from the jaws—the vertebræ and bones of the extremities, with but very few exceptions, scattered here and there—the stems of the plants torn to pieces; and these relics are intermixed with pebbles of quartz, flinty-slate, and jasper, affording evidence that these heterogeneous materials have been subjected to the action of water, yet it is manifest that the operation was fluviatile, not littoral. The pebbles, though smooth, are not rounded into beach or shingle; they have been worn by the action of streams and torrents, but not by the waves of the ocean. And when we consider that the ligaments and tendons of the joints, even of the existing lizards, possess such strength and tenacity, as to render the separation of their limbs extremely difficult, we cannot conceive that the gigantic limbs of the iguanodon and megalosaurus could have been dissevered without great violence, except by the decomposition of their tendons from long maceration; and if this process were alone the cause, the bones would not be found broken and apart from each other, but in apposition, as in the fishes of the chalk, where even the scales, gills, and fins, preserve their natural position.

The specimen of the hylæosaurus (page 401) throws much light on this question; many of the vertebræ and ribs are broken and splintered, but the fragments still remain near each other; the bones are dislocated, yet lie in a situation bearing some relation to their original state. These circumstances indicate that the carcase of the original must have suffered injury and mutilation, and that the dislocated and broken bones were held together by the muscles and integuments; in this state the headless trunk must have floated down the river, and at length sunk into the mud of the delta, and formed, as it were, a nucleus, around which the stems and leaves of palms and tree-ferns accumulated, and river shells became intermingled with the general mass.

The phenomena here contemplated appear to admit of but one explanation—that of a considerable period of transport; the carcases of the large reptiles must have long been exposed to such an agency, and the river which flowed through the country of the iguanodon, must have had its source far distant, perhaps thousands of miles, from the delta which it deposited. The course of that river —the extent of that delta—the situation of that country, will probably for ever remain unknown. These, as I conceive, are the conclusions which the facts we have examined substantiate.* I do not, however, mean to intimate that there are not proofs

* The Mississippi flows through twenty degrees of latitude and seven of longitude, and drains a valley 3000 miles long and nearly 1000 broad; its delta extends out to sea several hundred miles.

of the existence, in the northern hemisphere, of a higher temperature than at present, during the iguanodon epoch; on the contrary, the tropical plants and trees of Portland appear still to occupy the area in which they grew, and the nautili and polyparia of the chalk are not inhabitants of northern seas; but I will defer the further consideration of this problem, till other phenomena have been submitted to our examination.

4. MEDIAL SECONDARY FORMATIONS.—In accordance with the order of chronological arrangement (p. 194, Pl. VII.), I proceed to the description of the succeeding groups of the secondary formations, and shall comprise in the present discourse the consideration of, 1st, the *Oolitic*, 2d, the *Liassic*, and 3dly, the *Saliferous*, or *New Red Sandstone Systems*. The entire series consists of alternating beds of clay, limestone, sand, sandstone, marls, and conglomerates, which abound in marine exuviæ; the whole having manifestly been deposited in the basin of an ocean. The organic remains comprise a prodigious number of zoophytes, crinoidea, shells, cephalopoda, crustacea, fishes, and marine reptiles. Trees, plants, coal, lignite, and other vegetable remains, also occur, with wings of insects, bones of reptiles, and of two or more genera of terrestrial mammalia. Evidence is thus afforded of the existence of countries clothed with vegetation and tenanted by animals.

5. THE OOLITE, OR JURA LIMESTONE.—Lime-

stone composed of an aggregation of small rounded grains or spherules, is called *oolite*, or egg-stone, from its fancied resemblance to clusters of small eggs, or to the roe of a fish. As this structure, though not confined to the strata under consideration, very generally prevails in the limestones of this division of the Secondary, the term *Oolite* is employed to designate that group, which on the continent is called the Jura-limestone (*Jura Kalk*), from the mountain range of which it forms so essential a character.

As the plan of these Lectures only embraces a very general and familiar summary of geological phenomena, it would be irrelevant to enter upon details, which, however interesting to the geologist, would embarrass the general observer by the overwhelming mass of facts that would require his attention. It is, however, necessary to present an outline of the leading subdivisions of the oolite, in which the lias may also be included; for although the strata designated by these terms are separated in most artificial arrangements, we shall find it convenient, for the sake of brevity, to comprise them in one general survey.

6. TABULAR VIEW OF THE OOLITE AND LIAS.—The following tabular view, principally derived from the works of Professor Phillips, will obviate the necessity for detailed descriptions of the lithological characters of the deposits.

THE OOLITIC SYSTEM.

UPPER OOLITE of Portland, Wilts, Bucks, Berks, &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. 2. *Kimmeridge clay*—blue clay, with septaria and bands of sandy concretions—marine shells and other organic remains—*ostrea deltoidea*.
MIDDLE OOLITE of Oxford, Bucks, Yorkshire, &c.	1. *Coral-oolite*, or coral-rag—limestone composed of corals, with shells and echini. 2. *Oxford clay;* with septaria and numerous fossils—beds of calcareous grit, called Kelloway-rock, abounding in organic remains.
LOWER OOLITE of Gloucestershire, Oxfordshire, and Northamptonshire.	1. *Cornbrash*—a coarse shelly limestone. 2. *Forest marble*—sand, with concretions of fissile arenaceous limestone — coarse shelly oolite—sand, grit, and blue clay. 3. *Great oolite*—calcareous oolitic limestone and freestone; reptiles, corals, &c. upper beds shelly. *Stonesfield slate*—land plants, insects, reptiles, *mammalia*. 4. *Fuller's earth beds*—marls and clays, with fuller's earth — sandy limestones and shells. 5. *Inferior oolite*—coarse limestone—conglomerated masses of terebratulæ and other shells — ferruginous sand, and concretionary blocks of sandy limestone, and shells.
LOWER OOLITE of Brora in Scotland.	1. *Shelly limestones*—alternations of sandstones, shales, and ironstone, with plants. 2. *Ferruginous limestone*, with carbonized wood and shells. 3. *Sandstone and shale*, with *two beds of coal*.

Lower oolite of the Yorkshire coast.

1. *Cornbrash.*
2. *Sandstones and clays*, with land plants, *thin coal and shale*—calcareous sandstone and shelly limestone.
3. *Sandstone*, often carbonaceous, with clays, full of plants; *coal beds* and *ironstone.*
4. *Limestone*, ferruginous and concretionary sand.

THE LIAS.

Lias of Dorsetshire, Somersetshire, Northamptonshire, and Yorkshire.

1. *Upper lias shale*, full of saurian remains, belemnites, ammonites, &c. intercalated with the lowermost sand of the oolite—nodules and beds of limestone.
2. *Lias marlstone* — calcareous, sandy, and ferruginous strata, very rich in terebratulæ and other fossils.
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 of the strata, extensive as it appears, exhibits only the principal distinctions observable in the immense series of deposits, comprising the Oolite and Lias. The difference observable between the lower beds of the oolites, in the midland counties, and in Yorkshire and Scotland, is a fact of great interest; and the accumulation of vegetable matter in the state of coal, with the remains of terrestrial plants in Yorkshire and Brora, together with the presence of insects, land-plants, and mammalia, in the Stonesfield slate, attest the existence of land, and the action of rivers and currents. The observations on the nature of oceanic deposits in a previous lecture (page 47), will have prepared you for the appearance of such anomalies in the beds of the ancient seas.

7. Geographical distribution of the oolite and lias.—The oolite (comprehending in this term the series of strata above enumerated) forms a striking feature in the physical geography of England, from the southern shore near Exmouth to the Yorkshire coast. It constitutes a table-land of considerable elevation, the highest points attaining an altitude of 1500 feet, which extends in a tortuous line through Yorkshire, Lincolnshire, Northamptonshire, Oxfordshire, Gloucestershire, and Somersetshire, to the coast of Dorsetshire. It generally presents a bold escarpment to the west, and slopes regularly to the east, dividing the eastern and western drainage of that part of England.* The lias forms a district that runs parallel to the escarpment of the oolite, from beneath which it emerges, and traverses the country from the Yorkshire coast, near Redcar, to the cliffs at Lyme Regis. (See *Geological Map of England*, Plate X.)

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,

* Geology of Yorkshire, by John Phillips, Esq. F.R.S., Professor of Geology of King's College.

forms the great mass of the Jura mountains, and constitutes part of the chain of the Alps, where beds belonging to this group appear greatly altered in composition, by causes to which I have already alluded.

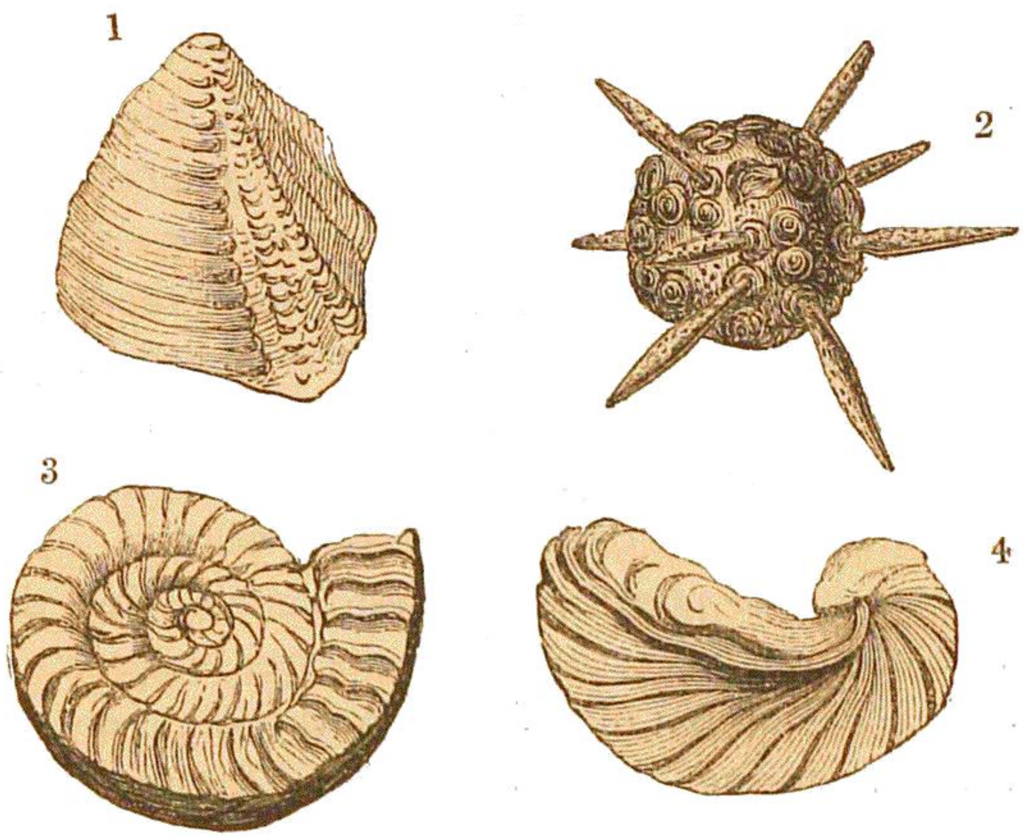
The usual characteristics of the lias are well preserved, even where those of the oolite are so blended as to render discrimination difficult. The lias of many parts of Germany can scarcely be distinguished from that of Dorsetshire; and at Boll, in Wirtemberg, Dr. Jaeger has discovered bones of ichthyosauri, and other peculiar liassic fossils.* Even in the Himalayas, argillaceous beds have been found with fossils which bear a close analogy to those of the lias.

Certain subdivisions of the oolite in England 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.

The upper beds of the oolite on the continent, are the lithographic slates of Pappenheim, Solenhofen, Monheim, &c., which abound in the fossil remains of flying reptiles, insects, crustacea, and marine shells. The Portland rock, which in

* Uber die Fossile Reptilien welche in Wurtemberg aufgefunden worden sind. Stutgard, 1828.

England is the uppermost division of the series, lies beneath the beds of fresh-water limestone, containing the petrified forest, described in the former lecture (page 362), and teems with ammonites and shells, particularly *trigoniæ* (Tab. 85, fig. 1), of which there are several species in this formation.



TAB. 85.—FOSSIL SHELLS OF THE OOLITE AND LIAS.

Fig. 1. Trigonia costata. 2. Cidaris with spines. 3. Ammonites Walcotii. 4. Gryphea incurva.

The *Kimmeridge* clay forms the base of the Isle of Portland, and contains, with numerous other marine shells, a flat species of oyster, *ostrea deltoidea*, so named from its peculiar shape; this shell is characteristic of the bed. The *Coral-rag*, or coralline oolite, is literally a petrified coral reef; it is a coarse limestone, almost entirely formed of madrepores, astreæ, and other stony corals, shells, and echini; sand, and pebbles fill up the interstices; the whole being consolidated by calcareous and silicious infiltrations. So obvious is the coralline structure, that the most incurious observer, travelling through the districts where the coral rag abounds, can scarcely fail to remark the blocks of corals which every where meet the eye. From the quarries near Faringdon, in Berks, I have collected, in the course of a few hours, hundreds of specimens of corals, shells, and echini; of the latter, the beautiful, tuberculated cidaris, popularly called *fairy's night-cap*, and its spines, (Tab. 85, fig. 2,) occur in great perfection.* The quarries of Calne, in Wiltshire, are particularly rich in these fossils.

The relative position of these divisions of the oolite with the cretaceous group, is seen in a section near Devizes, in Wiltshire, where the strata appear in the following order, (see Plate IX. fig. 2:)—1. Chalk; 2. Glauconite; 3. Galt; 4. Shanklin sand; 5. Kimmeridge clay; 6. Coral rag; 7. Oxford

* The heights around Faringdon are generally capped with green sand, 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 contain 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.

clay. South of Malmsbury, a continuation of the series to the lias may be observed (Plate IX. fig. 4). On the continent the coral rag is largely developed; and near Schaffhausen, and at Muggendorf, the oolite abounds in stony polyparia.

8. 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 shells, plants, and fishes; thus, while the chalk exhibits the bed of a deep sea with scarcely any intermixture of the land or fresh-water; and the wealden a delta in which no marine exuviæ are imbedded; the intercalations in the oolitic series present a combination of these characters, of which the Stonesfield strata afford a most interesting and instructive illustration.

Stonesfield, a small village near Woodstock, about twelve miles north-west of Oxford, has long been celebrated for the fossil productions of its slaty limestone, the bones and teeth of a large reptile (*megalosaurus*, Plate III. fig. 9), of fishes, and other remains, having been described and figured by Lhwyd, a century ago. The excellent work of Messrs. Conybeare and Phillips, which every one must regret is not 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 fresh-water character of the strata of Tilgate Forest, I was led to institute a comparison between the fossils of the wealden and those of Stonesfield, and the result appeared in my first work on the Geology of Sussex.† A valuable memoir by Dr. Buckland, on the megalosaurus, again drew attention to these interesting deposits, and hopes were entertained, that this distinguished philosopher would follow up his investigations, 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

* Geology of England and Wales, p. 207.

† Illustrations of the Geology of Sussex, page 37.

‡ Zoological Journal, vol. iii. page 416.

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 of strata are 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, by exposure to the frost, admits of separation into thin slates. The resemblance of this calciferous grit to that of Tilgate Forest is most striking; and when breaking it, and perceiving here and there teeth of crocodiles and other 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 oolite; beds of sands, clay, and friable, slaty sandstone, intervene between the layers of the oolitic, calciferous rock. Grits, similar to those of Stonesfield, occur at Wittering and Collyweston, associated with compact limestone and beds of oolite; they contain ferns and other terrestrial plants, and marine shells.

9. 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 fucus; of palms, tree-ferns, and many species of sphenopteris; 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 of reeds and grasses. I am not aware that the shells differ from those of the other oolitic strata; a small trigonia (*trigonia impressa*) is abundant. The bones and teeth of the gigantic reptile related to the monitor (the *megalosaurus*), which I have mentioned as occurring in the Tilgate grit; teeth and bones of crocodiles, bones and plates of turtles, bones of pterodactyles, or flying lizards, and other osseous remains, apparently of saurians, present a remarkable correspondence with the fossils of the wealden. The teeth, scales, fin-bones and rays of fishes, belong to the same genera and species as those contained in other beds of the oolite; the round hemispherical teeth of fish allied to the *lepidotus* of Tilgate Forest, are every where in profusion.

10. FOSSIL DIDELPHIS, OF OPOSSUM OF STONESFIELD.—But in addition to the extraordinary remains I have enumerated, the Stonesfield slate has

yielded to the geologist some of the most precious relics of the past ages of the globe—the only known examples of mammalian remains in the secondary formations; a fact, standing in this respect in the same rank with the discovery of birds in the

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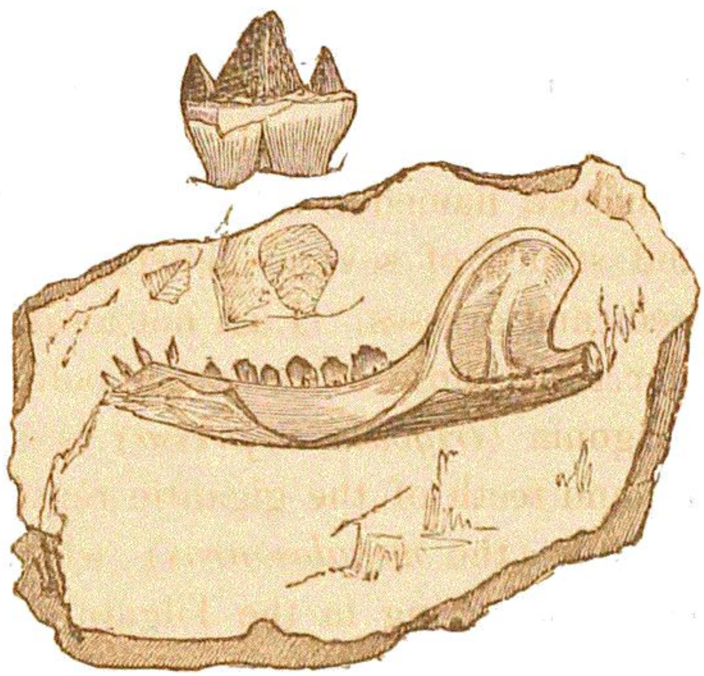

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TAB. 86.—LOWER JAW OF AN OPOSSUM, FROM STONESFIELD.

Didelphis Bucklandii.

*(From W. J. Broderip, Esq. F.R.S.)**

Fig. 1. The jaw of its natural size. 2. Second molar tooth, magnified six times.

wealden, but of still greater interest, since it carries back the existence of the higher vertebrated animals to a period far more remote. Four specimens of jaws have been discovered, which Mr. Broderip

* Zoological Journal: "Observations on the jaw of a fossil mammiferous animal in the Stonesfield slate," by W. J. Broderip, Esq.

refers to three different species, if not genera. The true affinities of the fossils were determined by Baron Cuvier.* Mr. Broderip's specimen (Tab. 86) consists of the right half of a lower jaw, the inside of which is exposed; it has seven grinders; one canine, and three incisor teeth; there is a vacancy for a fourth incisor, and thus the number would correspond with the dentition of the recent didelphis. This fossil 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 occurs in such profusion in the Stonesfield slate.

11. WEALDEN AND STONESFIELD FOSSILS.—A comparative view of the organic remains of the wealden and of the Stonesfield slate, exhibits a striking analogy in the zoological characters of these deposits.

Wealden Grit of Tilgate Forest.	*Stonesfield Slate.*
Wood, in the state of a reddish brown friable mass.	Wood.
Equiseta.	Fuci.
Sphenopteris, Lonchopteris, and other ferns.	Sphenopteris, Tæniopteris, and other ferns.

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* On the Megalosaurus of Stonesfield: Geological Transactions, vol. i. page 393. Second Series.

M. Blainville has lately drawn attention to the subject, by asserting that these jaws belong to unknown reptiles; but there does not appear to be any reason to doubt the correctness of the deduction of M. Cuvier.

Wealden Grit of Tilgate Forest.	*Stonesfield Slate.*
Cycas, or zamia.	Cycas, or zamia.
Liliaceæ.	Liliaceæ.
Clathraria Lyellii.	Arborescent ferns.
Coniferæ.	Coniferæ.
Seed-vessels—undetermined.	Seed-vessels—undetermined.
Fresh-water shells.	*Marine shells.*
Cypris—*fresh-water crustacea.*	Astacus—*marine crustacea.*
No insects have been discovered.	*Insects—coleoptera.*
Fishes of the genera hybodus, ptychodus, &c.	Ptychodus, hybodus, and other fishes.
Lepidotus.	Lepidotus?
Marine and fresh-water turtles.	Turtles.
Plesiosaurus.	Plesiosaurus.
Pterodactyles.	Pterodactyles.
Crocodiles.	Crocodiles.
Megalosaurus.	Megalosaurus.
Iguanodon, hylæosaurus, and other reptiles.	Other reptiles.
Bird—ardea.	*Mammalia—didelphis.*

The remains of *cetacea* do not occur in either of the deposits.

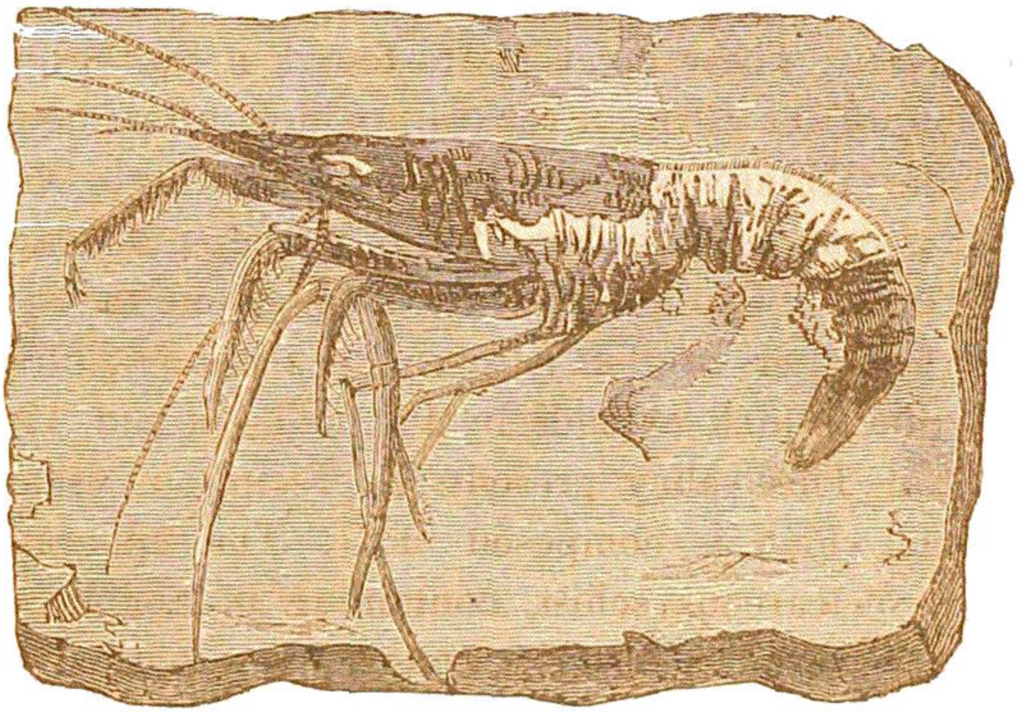
From this tabular view, we perceive that the flora and fauna of the wealden agree in every essential character with those of Stonesfield; the mollusca denote the respective conditions in which the accumulation of the strata took place—the wealden in the embouchure of a river—the Stonesfield beds in the basin of a deep sea.

12. Lithographic slates of Pappenheim, Solenhofen, and Monheim.—In the Stonesfield and Collyweston grit and shale, we have examples of the occurrence of land animals and plants in the

lowermost division of the oolitic system. In Germany, the uppermost part of the group consists of shales, and layers of a fine grained, fissile limestone much employed in lithography, and which afford an assemblage of organic remains of surpassing interest. These 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 Danube, which 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, crustacea, 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, which constitutes the base of the hills of that district. The most celebrated quarry of the calcareous schists, is that of Solenhofen, in the valley of Altmuhl, near Pappenheim.* The cream-coloured limestone of this quarry has long been known to contain organic remains of great beauty and interest. Crustacea 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

* Oss. Foss. Tom. V.

Catastrophes que le Globe terrestre a essuié," contains coloured representations of crabs, *astacidæ*, &c. The fossil prawn here figured shows the extraordinary state of preservation of these remains. A



TAB. 87.—FOSSIL PRAWN, FROM PAPPENHEIM.
(Palæmon spinipes.)

saurian, about three feet in length, allied to the crocodile, and numerous flying reptiles, have been found at Solenhofen; and Count Munster has collected seven species of pterodactyles, six saurians, three tortoises, sixty species of fish, forty-six of crustacea, and twenty-six of insects. The number of testacea is comparatively small, as also of plants, which are all marine. The cabinet of Mrs. Murchison contains a beautiful *libellula*, or dragon-fly, from Solenhofen.* Mr. De la Beche remarks, that

* Geological Manual, p. 372.

the fact of the greatest number of fossil insects yet noticed in the oolite, having been found where the remains of the pterodactyles also 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. The same geologist considers it probable that these lithographic limestones may have been deposited contemporaneously with the wealden.

13. COAL OF THE OOLITE.—In the tertiary system of Provence, we noticed the occurrence of beds of coal and carboniferous strata, with limestone containing fresh-water shells and crustacea (page 245); and in the lacustrine deposits of the Rhine, accumulations of brown coal, or lignite (page 269). In the wealden, lignite was also observed; and in some localities (as at Bexhill, in Sussex,) in such abundance, and associated with shales and laminated sandstones, so much resembling the ancient carboniferous beds, as to have led to an expensive and abortive search for coal. The lower division of the oolite in Yorkshire, and in Scotland, contains coal formations; and as these exhibit the transmutation of vegetable substances into a carbonaceous mass, under circumstances widely different from the examples we have hitherto noticed, I will offer a few remarks on these deposits.

Professor Phillips, who has so ably investigated the geology of Yorkshire,* has given a lucid description of the carboniferous strata of the oolite;† and Mr. Murchison, of those of Brora, in Sutherland. The tabular arrangement of the oolitic system (page 437) shows the succession of the deposits in Yorkshire and Brora.

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-beds of sandstone, shales abounding in coaly matter, are 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 thickness, is, from local circumstances, 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 Brandsby. 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

* The Geology of Yorkshire.

† Ency. Metrop. art. Geology.

ferns, equiseta, cycadeæ, and of a great many other plants, it is chiselled out by collectors, to obtain specimens. The beauty and variety of these fossil plants are shown in this interesting and extensive series, presented to me by Dr. Peter Murray, and Mr. Williamson, of Scarborough. "Here," observes Professor Phillips, "we have truly a coal-field of the oolitic era, produced by the interposition of vast quantities of sedimentary deposits, brought down by floods from the land, between the more exclusively marine strata of the ordinary oolitic type."

Mr. Murchison, one of our most distinguished and indefatigable geologists, has ascertained that this oolitic carboniferous system extends yet farther northward; and at Brora, and other parts of Sutherland, and on the western coast of Scotland, contains beds of coal of considerable extent. At Brora the sandstones and shales acquire considerable thickness, and frequently alternate with layers of plants and beds of coal, from a few inches to nearly four feet in thickness. On the north-east coast of the Isle of Skye, shales and sandstones, with impressions and remains of plants, form an extensive series of strata above the lias shale.

14. GEOGRAPHICAL DISTRIBUTION OF THE LIAS.—I have stated, in general terms, that the lias in England extends along the western escarpment of the oolite, forming a district which presents an exceedingly variable surface, occasioned by the

disruptions of the strata, and subsequent denudations. Its course and extent, 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 moor lands, 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 borders of Nottingham and Lincoln, and the celebrated quarries of 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 course 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 Glamorgan-

* Outlines of the Geology of England and Wales, p. 261.

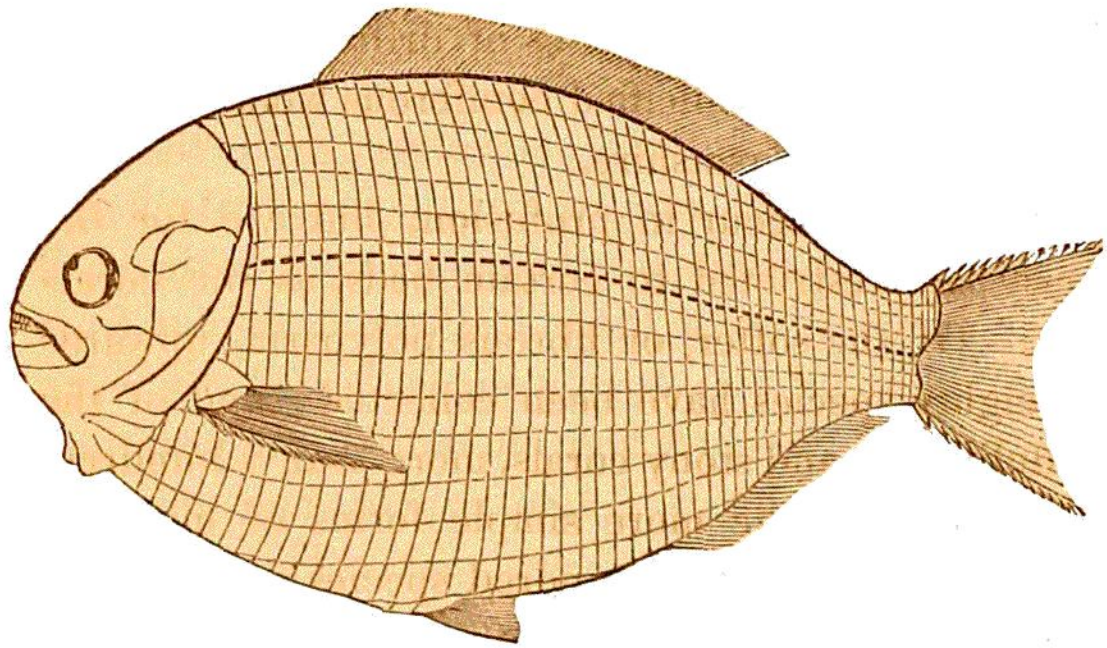
shire, and attended with numerous outlying, or detached masses. To render the course and position of the lias in this quarter intelligible, it is necessary to state, that this district is occupied by three great basins of the coal formation, encircled by the subjacent rocks of limestone and old red sandstone (see *Map*, Pl. X.), to be noticed in a subsequent lecture. 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 strata of lias, with subjacent beds of red marl, are seen lying unconformably (*definition*, page 192) upon the highly inclined strata of the coal measures (Mendip hills, Pl. IX, 2). I shall recur to this subject hereafter, and now only observe, that the lias is seen beneath the oolite through the south-east of Somersetshire, and passes into Dorsetshire, where the overlying strata of the Shanklin sand conceal it beneath the high range of the Black Down hills. At Lyme it forms a range of cliffs, about four miles in length, and may be traced till it gradually sinks beneath the inferior oolite. The fossil skeletons of large marine reptiles, 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, exhibit 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 through a large extent in Germany, the lias, with its peculiar fossils, accompanies the oolite. One species of bivalve, the gryphite (*gryphea incurva*, Tab. 85, fig. 4), which is so constant in the liassic strata of England, on the continent forms whole beds of limestone (*calcaire à gryphites*), which, like the Sussex marble, is composed of shells cemented together by a calcareous paste. In Wirtemberg (as I have elsewhere stated) the lias presents the usual characters of that of England, and ichthyosauri and other saurians occur in considerable abundance. In the valley of the Arve, in Switzerland, the argillaceous beds of lias are of great thickness; and, owing to the ancient effects of igneous agency, everywhere so apparent in the Alps, have a schistose character, strongly assimilating them to the primary slates.

15. ORGANIC REMAINS OF THE OOLITE AND LIAS.—From the immense number and variety of the organic remains already discovered in the oolitic and liassic strata, I shall only offer a few general remarks on the plants, mollusca, and fishes, that our attention may be more fully directed to the reptiles which constitute so extraordinary a feature in the zoology of the secondary formations. My observations on this interesting subject will be introduced in a subsequent part of this discourse.

Plants.—Two or three species of fucus, and upwards of forty terrestrial plants, are enumerated in the catalogue of Mr. De la Beche: among these is a large species of mare's-tail (*equisetum columnare*), many ferns, cycadeæ, coniferæ, and liliæ: the greater part of the land plants have been obtained from the coal shale of Yorkshire, and the slate of Stonesfield; masses of drifted wood bored by lithodomi, and silicified coniferous wood, abound in the lias of Dorsetshire.

Zoophytes occur in profusion, but are for the most part restricted to certain beds, as the coral-rag. Of the softer, or fibrous polyparia, upwards of eighty species have been collected; and of the celluliferous and stony corals, more than a hundred. The shells of the more simple forms of mollusca amount to five or six hundred species; and of the cephalopoda, as the nautili, ammonites, belemnites, &c. to more than three hundred. Echinites, of at least fifty species; five or six star-fish; and several species and genera of those curious forms of radiaria, the *crinoidea*, or lily-shaped animals, have been collected. Specimens of the genus *pentacrinus* occur in the lias shale of Lyme, with the ossicula, or little bones, which compose their skeletons, changed into brilliant pyrites. I shall defer a particular description of these relics, as well as of fossil zoophytes in general, to the lecture on corals. Crustacea, and insects of many species, have been found in some localities. The fishes of the oolite are in the progress of illustration by M. Agassiz, who describes the families of *pycnodontes* (thick toothed) and *lepidoides* (with thick scales) as prevailing most extensively during the oolitic era; the round, subconical, shining teeth of the one, and the lozenge-shaped, polished scales of the other, are



TAB. 88.—RESTORED FIGURE OF THE DAPEDIUS OF THE LIAS.

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

abundant in the limestone. In the lias, the teeth, scales, bones, and perfect examples of fish, particularly of the genus *dapedius* (Tab. 88), have been found, together with many others, of which specimens are in my museum. More than forty species of reptiles have been described, and there are still many undetermined; of mammalia, two genera, as I have previously stated, have been discovered.

16. STATE OF FOSSILIZATION.—The state of preservation of the organic remains, of course varies with the nature of the strata in which they are

imbedded: in the oolitic limestone the shells are commonly changed into calcareous spar, and their cavities lined with crystals; the corals also have undergone a similar transmutation. The ammonites and nautili frequently have their chambers filled with spar of various colours, and when cut and polished exhibit highly interesting and beautiful sections of the internal structure. In the lias shales, ammonites are met with in great profusion; in some examples the pearly coat of the shell alone remains, as in these brilliant examples from Watchett: in this specimen, collected by Mrs. Murchison, the shell and all its delicate partitions or septa are converted into pyrites, and the cells filled with white calcareous spar. The nacreous, horny sheath and ink-bag of the belemno-sepia (p. 317) are frequently preserved. In the limestone the bones have the same rich sienna tint as those of Tilgate Forest; but in the lias they are of a dark-bluish grey or black, and often coated with sulphuret of iron. The most remarkable circumstance relating to the remains of the reptiles is the state of apposition in which the bones of the skeletons are commonly found. The entire osseous frame-work, from the extremity of the beak to the last vertebra of the tail, and the terminal bones of the paddles, often remain in contact; a fact proving that the body was engulfed before decomposition had far advanced, and that the carcase had not been long drifted or abraded by the waves; the ichthyosauri and plesiosauri of Mr. Hawkins, in the British Museum, are proofs of the correctness of this inference.

The general character of the oolite, as derived from its organic remains, is therefore that of a system of oceanic deposits, accumulated in a basin of great extent, through a period of immense duration. The sea was inhabited by the general classes of marine animals, but of genera and species that became extinct before the tertiary epoch; and with these were associated multitudes of peculiar reptiles. The land which then existed, as attested by the remains drifted into the basin of the sea, was peopled by reptiles and marsupial animals, and clothed with tree-ferns, palms, cycadeæ, and coniferæ.

17. SALIFEROUS, OR NEW RED SANDSTONE SYSTEM.—Beneath the lias (see tabular arrangement, page 194, Plate VII.) are beds of marl, of various colours, but in which a dull red, derived from peroxide of iron, generally predominates; and limestones, containing a considerable portion of magnesia. These strata are associated with saliferous marls, which abound in chloride of sodium, or common salt, and sometimes include vast beds of that mineral, with scarcely any intermixture of other substances. The term saliferous is therefore applied to the group, although deposits of salt are not confined to these strata, but occur (page 276) even in the tertiary. This formation naturally

presents the following divisions:—1. The uppermost, or *New red sandstone*, comprising the marls and conglomerates, with gypsum and rock salt. 2. The *Magnesian limestone*, which consists of limestones, conglomerates, and calcareous breccia. This system is interposed between the lias and the grand deposits of coal, as represented in the plan, Pl. 7; its position in natural sections is seen in the sketch of the Mendip Hills (Pl. 9, figs. II. and IV.), and in Pl. 10, where it is shown to overlie the coal measures near Durham. The lower beds of this formation, in some districts, pass insensibly into the carboniferous series below, and into the lias above, presenting a natural transition from the one group to the other; yet there are certain characters which render the strata recognisable even in distant regions.

Although the organic remains, which are very locally distributed in this system, correspond in many respects with those of the lias, oolite, and coal, some animals and plants occur which are presumed to be peculiar, from their presence in the new red sandstone, and absence in the formations between which it is interposed,—for instance, the coniferous plants of the genus *Voltzia*.*

18. Tabular view of the saliferous strata.—The following is a tabular arrangement of the principal deposits of the saliferous system.

* These plants, named after an eminent geologist and naturalist, M. Voltz, of Strasburg, will be described in the seventh lecture.

New or Upper Red Marl or Sandstone.

(*Comprising the Grès bigarré of the French, and the Muschelkalk and Keuper of the German geologists.**)

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

Total thickness, about 300 yards.

Magnesian Limestone or Zechstein.

1. Red and white marls.
2. Magnesian limestone; white, red, or yellowish limestone, with a large proportion of magnesia, in thick beds, with marine organic remains.
3. Marl slate, in thin layers, containing reptiles and fishes. The *Keuper schist* of Mansfeld.
4. Marls and variegated sandstones, with sands and clays of variable thickness and character.

Total thickness, 100 yards.

From this general view, the saliferous system is seen to consist of a series of blue marls, red sandstones, magnesian limestones, and conglomerates, more or less coloured with peroxide of iron; the upper divisions containing 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, plesiosauri and

* De la Beche. Geolog. Man. p. 376.

other reptiles of the lias, abound. This formation contains a few metallic veins, and some of the foreign divisions are rich in iron ore.

19. GEOGRAPHICAL DISTRIBUTION OF THE SALIFEROUS STRATA.*—The geographical position and relation of the new red sandstone in England is very irregular. From the river Tees on the Yorkshire coast, the line of its emergence from beneath the lias forms its eastern boundary, and it runs nearly parallel with the western branch of that formation, to the Dorsetshire and Devonshire coasts, near Lyme, Sidmouth, and Torbay. But the district of which it forms the sub-soil is exceedingly variable in breadth, from the extension of its western limits, as may be seen by any large geological map of England. This arises from the saliferous strata being the last of the nearly horizontal, conformable beds of the eastern and southern counties; the underlying strata being thrown up at various and often considerable angles, and into lofty groups and chains of mountains, which appear like so many islands amidst the great plain of the red marl. From Yorkshire to Nottingham it constitutes a tract of a somewhat uniform breadth of twelve miles. In many parts of Nottinghamshire gypsum occurs in these deposits; and a quartzose gravel, consolidated into a breccia, covers a considerable area, and forms the Castle hill of Nottingham. Passing on to Derby and Leicester, the red marl

* An Abstract from the Geology of England and Wales.

spreads into a vast plain, which occupies nearly the whole of Cheshire, and the southern part of Lancashire and Shropshire, and forms the grand depository of rock salt. In Derbyshire, gypsum or alabaster is largely obtained from strata of this formation, and is manufactured into pillars, vases, and other ornamental articles; ear-rings and necklaces are made of the fibrous gypsum, or satin spar. The magnesian limestone range, 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 from opposite the Devonshire coast skirting the transition rocks of Brittany, and to the west underlying the Jura limestone, and containing 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. In North America the new red sandstone 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 shale, with fishes resembling those of

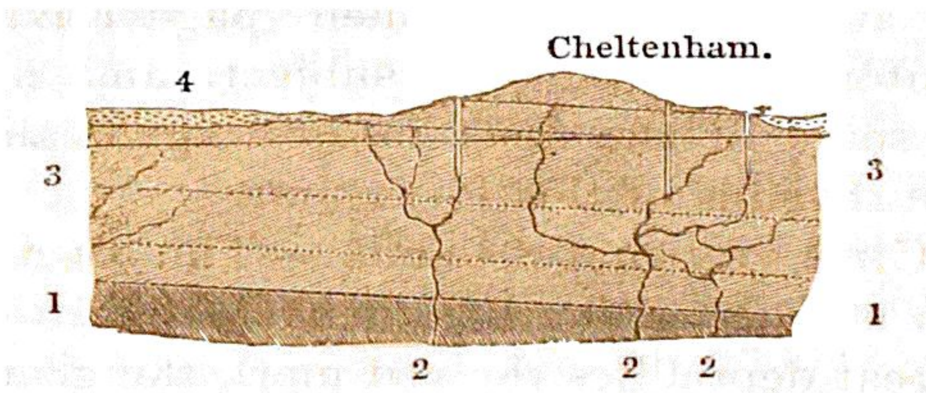
* Phillips.

Mansfeld.* In the plains of the Mississippi, strata referable to this group are said to occur between the Alleghany mountains. But I must refer you to the authors already named (page 186) for farther information on this subject, and hasten to notice some of the most interesting localities and organic remains of this formation.

20. CHELTENHAM WATERS.—The town of Cheltenham is built on the lias, beneath which, but at a very great depth, lies the red marl, the grand depository of the rock-salt and brine-springs of England. The celebrated mineral waters of Cheltenham flow up through the lias, but have their origin in the red marl upon which it rests; from this bed they derive their saliferous ingredients, and undergo various modifications in their passage through the lias. From the analyses of these 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 was desirous of ascertaining whether these two active principles, which the French chemists had recently

* 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 sanction it was undertaken.

discovered in modern marine productions, did not also exist in mineral salt-waters, issuing from strata that were formerly beneath the sea. The red mar



TAB. 89.—SECTION OF THE LIAS AT CHELTENHAM.

(By Mr. Murchison.)

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

is the source whence the waters derive their saline properties, but, as the springs pass through the lias marls, which are full of iron pyrites or sulphate of iron, certain chemical changes are effected, and the waters acquire their celebrated medicinal qualities. 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. 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 and more valuable properties as they ascend to the places from whence they flow. At the same time it must be borne in mind that fresh water is perpetually falling from the atmosphere upon the surface of the lias clay, and more or less percolating through its uppermost strata."*

21. ROCK-SALT AND BRINE-SPRINGS.—Brine-springs, emanating from water flowing through subterranean masses of salt, occur in the great plains of the red sandstone of Cheshire. The depositories of salt do not however extend over the strata in a connected bed, but occupy 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 long been celebrated for the production of salt from its brine-springs, which appear to be inexhaustible. 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; this brine, the purity of which is considered superior to that of any other,

* Outline of the Geology of the Neighbourhood of Cheltenham, by R. I. Murchison, Esq. F.R.S. Cheltenham, 1834.

produces about 700,000 bushels of salt annually. At a distance of from thirty to forty feet below the surface is a hard bed of gypsum, which is generally about 150 feet thick: through this a small hole is bored to the river of brine, which is in depth about twenty-two inches, and beneath which is a hard rock of 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. In the present state of our knowledge the origin of these beds of pure salt cannot be satisfactorily explained; for if we suppose them to have arisen from a mere evaporation of sea-water, it is difficult to account for the absence of all extraneous matter; it is more probable that their origin may in some measure be due to igneous action, as chloride of sodium is one of the products of volcanic emanations. The occurrence of the two most powerful acids, sulphuric (in the gypsum, or sulphate of lime), and the muriatic (in the salt), so largely associated together, is a fact which, in a more advanced state of chemical science, may probably throw light on this question.*

22. MAGNESIAN LIMESTONE, OR ZECHSTEIN.—The magnesian limestone is generally of a light

* Bakewell's Geology, p. 251. Lyell's Principles of Geology, vol. ii. p. 17.

fawn or yellow colour, and in some parts is of a crystalline, in others of a concretionary character. In many places, and particularly in the quarries around Sunderland, it presents a beautiful example of spheroidal structure, evidently superinduced on stratified detritus *after its deposition;* for the laminæ traverse the globular masses uninterruptedly, as in the grit of Tilgate Forest, and appear to have been occasioned by a slow chemical segregation of the materials. These clusters of spheroids, from the magnesian limestone near Sunderland, exhibit the principal varieties; some of them partake so much of the appearance of organic remains as to have been mistaken for fossils. In chalk the same structure sometimes prevails, as in these examples from Preston chalk-pit, near Brighton, discovered by my son, Mr. Walter Mantell. The limestone is commonly traversed by veins or strings of carbonate of lime, and occasionally incloses hollow spheroids of calcareous spar, with sulphate of strontian and barytes. Galena, sulphuret of zinc, and carbonate of copper, occasionally occur. At Mansfeld, in Germany, beds of slate, abounding in copper (*keuper schist*), and containing fossil fishes of a peculiar character, are intercalated in this rock.

23. CONGLOMERATES OF THE NEW RED SANDSTONE.—The conglomerates of this formation are chiefly composed of materials derived from the disintegration of more ancient rocks; fragments and pebbles of slate, quartz rock, granite, porphyry,

&c.; even the fine silicious sandstones have a large proportion of the detritus of other beds. 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 containing pebbles of quartz and primary rocks.*

But the most interesting of these conglomerates, or breccias, in this country, are those in which eruptions of lava appear to have been thrown into the ocean of the new red sand, and to have cemented together the water-worn materials, so as to form a *trap conglomerate;* such at least seems 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 mass, 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 filled or lined with manganese, calc-spar, or jasper; a structure termed amygdaloidal (almond-like) in geology; the substance of the rock is an earthy felspar.

* Bakewell's *Geology*, p. 237.

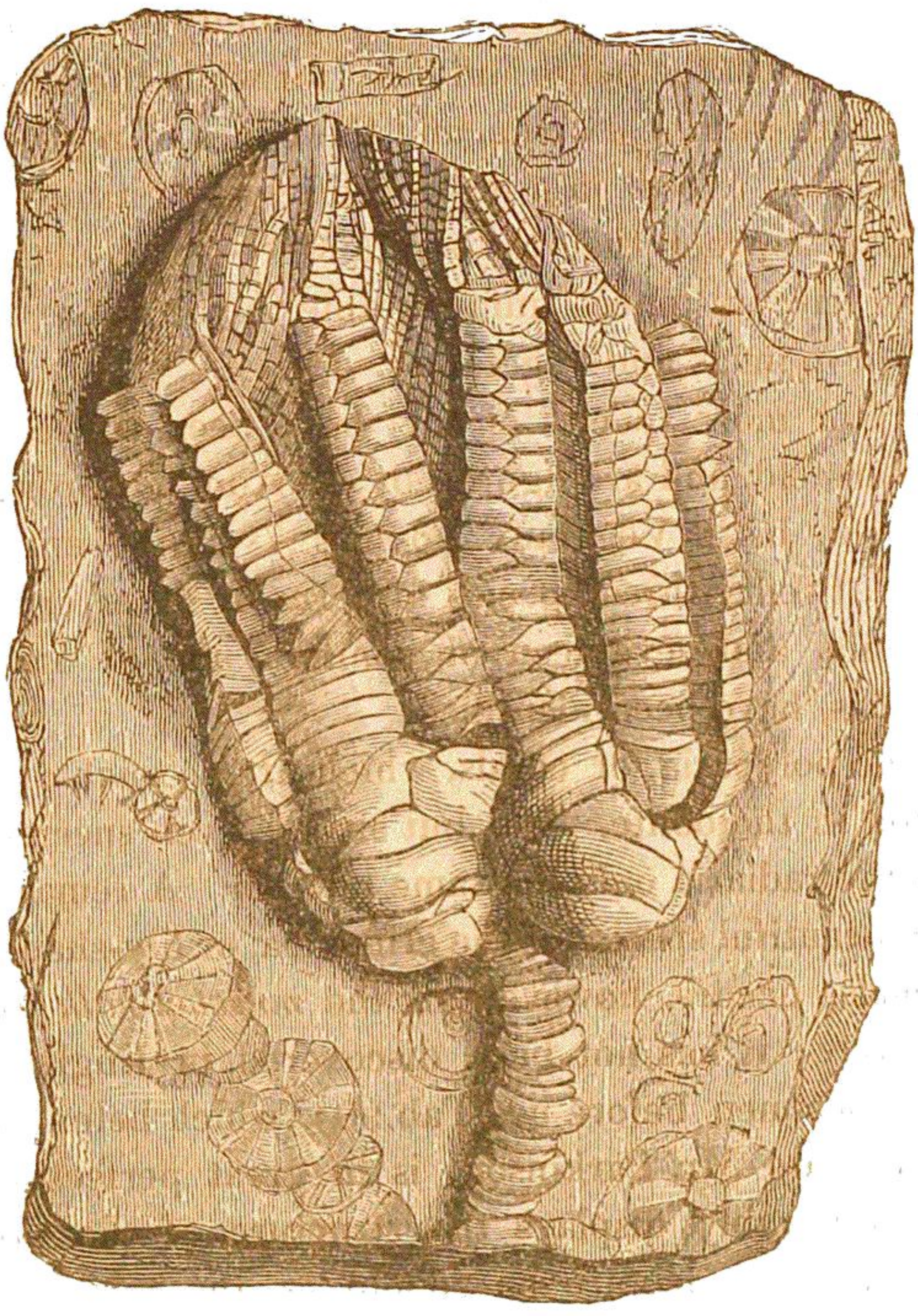
† Geology of England and Wales, p. 294.

24. ORGANIC REMAINS OF THE SALIFEROUS STRATA.—The new red sandstone formation presents a remarkable contrast, in the paucity of organic remains, with the oolite and lias; for while the latter teem with marine exuviæ, and the bones of reptiles, the former, except in a few localities, is destitute of fossils; a proof that the strata were accumulated under circumstances unfavourable to the preservation of animals and vegetables.

Six or more species of fuci have been collected at Mansfeld, and are figured by M. Adolphe Brongniart, in his "Végétaux Fossiles;" in the entire series, twenty-three species of ferns or other cryptogamia, and seventeen of coniferæ and of other families, have been identified.

The polyparia, or corals, which are in such profusion in the oolite, yield but six or seven species; and the radiaria only the same number. A remarkably beautiful species of the crinoidea, or lily-shaped animals, occurs, however, in the *muschel-kalk* exclusively; it has not been discovered in England. The specimen before us (Tab.90), which belonged to the late Mr. Parkinson, is in great perfection, and admirably displays the structure of the original; in the lecture on zoophytes, the nature of the singular family to which it is referable will be explained.

Ammonites, nautili, belemnites, and about one hundred species of other mollusca, are specified as having been collected in the various strata of this formation. Among these, two genera of bivalve shells, the species of which were formerly referred

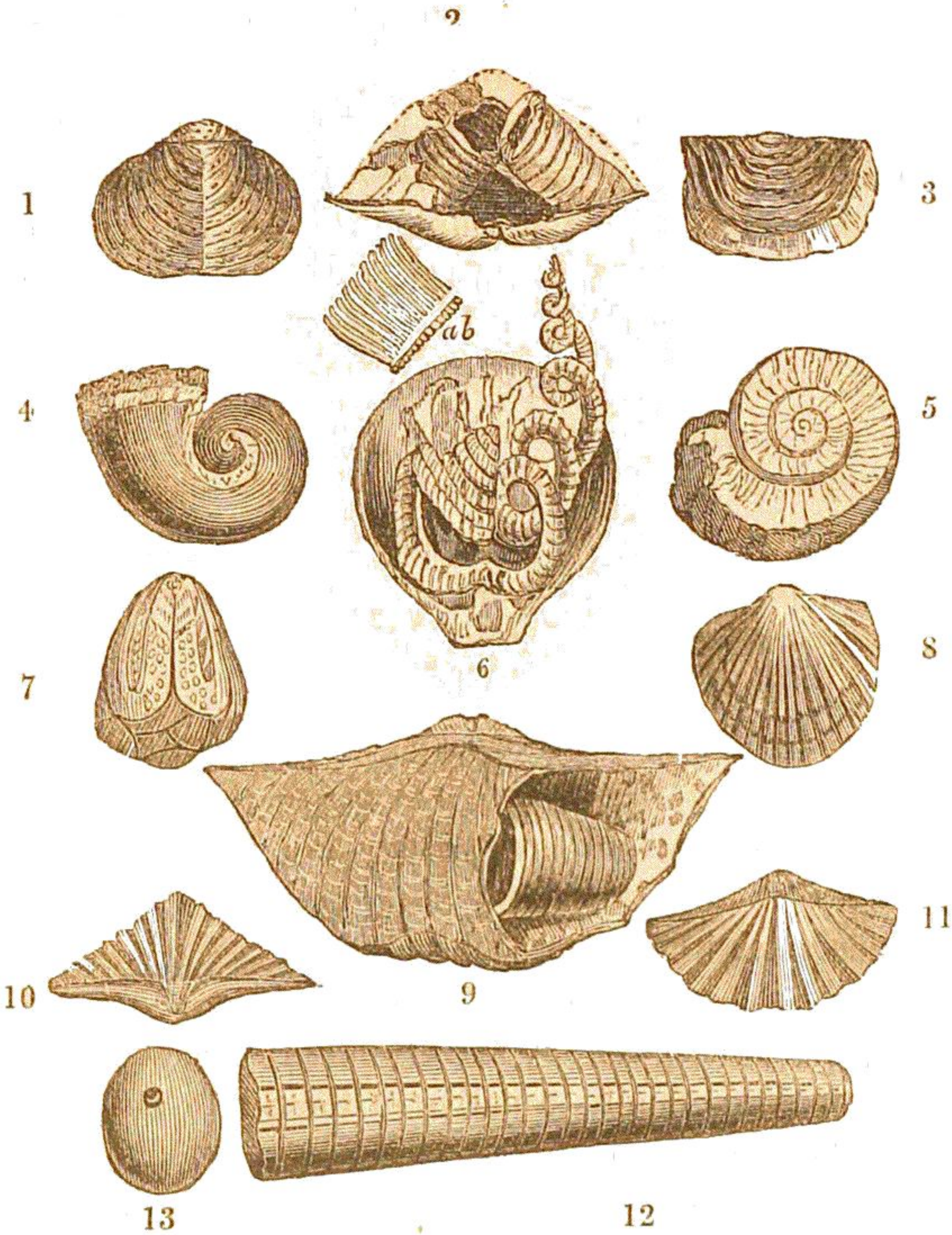


TAB. 90.—THE LILY ENCRINITE, FROM BRUNSWICK.
(*Encrinus moniliformis.*)

to anomia and terebratula, first appear, namely, *producta* and *spirifera;* in the older strata, which we shall hereafter examine, various species of these shells will be found to swarm in the rocks.

25. THE SPIRIFERÆ.—I will in this place offer a few remarks on the *spiriferæ*, that I may introduce the interesting account of the structure of the recent analogues, by my friend Professor Owen, of the Royal College of Surgeons. 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 spiriferæ (Tab. 91, figs. 2, 6, 9, 10, 11,) there are two spiral appendages (hence the name of the genus) which are closely coiled, and are often, like the substance of the shell itself, changed into calcareous spar, (see figs. 2, 9); in specimens where the shell is removed, these organs may be seen in their original situation. The following description, by Mr. Owen, of a recent animal of the same family, a native of the South Seas, will explain 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 (Tab. 91, fig. 6), two spiral arms, fringed at their outer margins, are seen to arise from these processes; these arms are quite



TAB. 91.—FOSSILS OF THE NEW RED SANDSTONE, TRANSITION SERIES, &c.

Fig. 1. Producta punctata. 2. Spirifera trigonalis, with spiral processes, from the mountain limestone. 3. Producta depressa. 4. Bellerophon cornu-arietis. 5. Euomphalus pentangulatus; carboniferous limestone. 6. Recent terebratula psittacea, showing the spiral arms. *ab*, Cilia of the arms magnified. 7. Pentremites ellipticus; carboniferous formation. 8. Terebratula affinis. 9. Spirifera trigonalis. 10. Spirifera triangularis. 11. Spirifera octoplicata. 12. Orthoceratite. 13. Septum of orthoceratite.

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 toward their extremities. The mechanism by which the arms is extended is most beautiful and simple; the stems are hollow from one end to the other, and are 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 respiration, as well as the nutrition, of animals living beneath a pressure of from sixty to ninety fathoms of sea-water, are subjects of peculiar interest, and prepare the mind to contemplate, with less surprise, the wonderful complexity exhibited in the minutest parts of the frame of these diminutive creatures. In the stillness pervading these abysses, they can only maintain existence by exciting a perpetual current around them, in order to dissipate the water already loaded with their effete particles, and bring within the reach of their prehensile organs the animalculæ adapted for their support.

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 *Ter.*

psittacea had been so sustained, this species would have presented in a fossil state, an internal structure very similar to that of *Spirifer*."*

Fishes.—Fifteen species, of a genus (*Palæoniscus*) supposed to be peculiar to this formation, have been discovered at Mansfeld; and ichthyolites of the same genus have been found in England, and in North America.

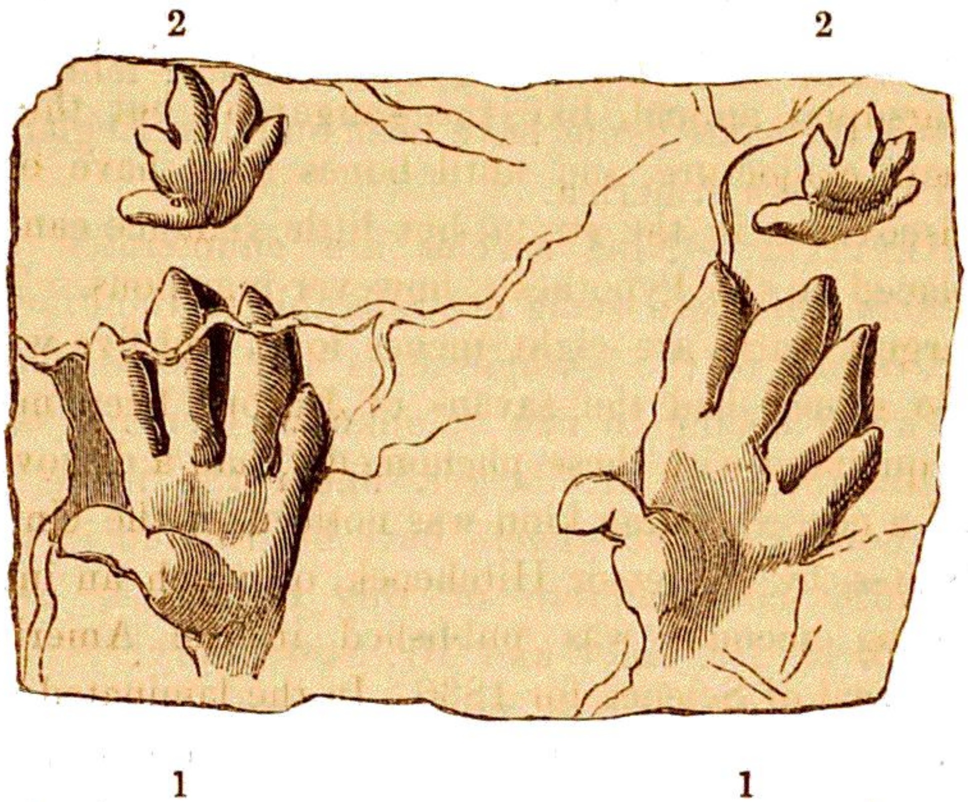
Reptiles.—Nine species are enumerated by authors: of these some are referable to the crocodile, others to the ichthyosaurus and plesiosaurus, and a few belong to new or unknown genera; one is described by Dr. Jaeger, under the name of *phytosaurus*. Two genera have been found in the dolomitic conglomerate of this formation, near Bristol, by Dr. Riley and Mr. Stutchbury.

26. Impressions of the feet of animals on sandstone.—A few years since, the attention of geologists was called to the remarkable occurrence of the impressions of the feet of some unknown animal, on blocks of the new red sandstone, at Corncockle Muir, in Dumfriesshire; the prints were supposed to resemble those made by the paws of

* Tab. 91, fig. 6, page 475. *Terebratula psittacea*, with the perforated valve and lobe of the mantle removed to show the fringed brachia or labial arms, one of which has been artificially unfolded. (Zool. Trans. Pl. XXII. fig. 14.)

Fig. *a b*. A portion of the ciliary fringe of one of the spiral arms magnified.—*Professor Owen on the Anatomy of the Brachiopoda, Zoological Transactions*, vol. i. p. 145.

turtles, as I shall hereafter explain.* A discovery of a similar nature has since taken place in Saxony, at a village near Hildburghausen. In a quartzose sandstone, footsteps of various sizes occur, disposed



TAB. 92.—FOOT-MARKS OF AN UNKNOWN ANIMAL ON SANDSTONE; FROM HILDBURGHAUSEN.†

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

in tracks, following each other as if the animals had leisurely walked over soft sand (Tab. 92); slabs of the stone, with the impressions, may be seen in the British Museum. There are distinct imprints of both the fore and hind feet, the

* 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.

† See Dr. Buckland's Bridgewater Essay, page 26.

latter being more than twice as large as the former. It has been ascertained that a similar disproportion is observable in the footmarks of bears. Some of the impressions exhibit distinct marks of nails. These singular appearances are supposed to have been produced by imprints of the feet of a marsupial animal, like the kangaroo; but this is mere conjecture, and until bones shall have been discovered in the strata, but little reliance can be placed on the hypothesis, however ingenious. The largest marks are eight inches long, and five wide. No sooner had the savans of Europe been made acquainted with these phenomena, than a discovery of a corresponding kind was noticed in the United States, by Professor Hitchcock, of which an interesting account was published in the American Journal of Science for 1836. In the laminated new red sandstone, which is spread over the valley of the Connecticut, numerous foot-prints appear on the surface of the sandstones when split asunder, exactly in the same manner as the ripple-marks on the Tilgate grit (page 356). These impressions are supposed by Professor Hitchcock to have been made by the footsteps of birds: if this opinion be correct, it is clear that the feathered tribes of that ancient epoch were the iguanodons of their race, for the dimensions of one kind of foot-mark are *fifteen inches long*, exclusively of the large claws, which are two inches in length; a proportion twice as large as those of the ostrich! The impressions are referable to six or seven species, which differ in size and proportion.* No bones have been found in the stone; but scales of the same genus of fish (*palæoniscus*) occur as in the saliferous sandstones of Europe. Very recently, numerous impressions resembling those observed at Hildburghausen have been noticed in the quarries of Storton Hill, near Liverpool, together with markings, which some geologists suppose to be the undoubted tracks of many different kinds of reptiles; but until bones shall be discovered, the nature of these appearances must be considered as very problematical; the facts, nevertheless, are extraordinary, and may lead to highly interesting results.

27. Reptiles.—I have reserved for this lecture some observations on the organization of reptiles, which may be necessary to enable the unscientific inquirer fully to comprehend the inferences that arise from an investigation of the fossil remains of this class of beings.

All animals possess organs by which a certain change is effected in the circulating fluid, to refit it for the purposes of nutrition. Land animals 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 animals, this apparatus is the gills, which are

* American Journal of Science, 1836. Dr. Buckland's Essay contains an interesting account of these discoveries, illustrated by several plates.

instruments 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 the process of vitality maintained. In reptiles, the respiratory organs are less developed than in any of the other vertebrated animals; the heart 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 blood, they dive with facility, and remain under water for a long period without inconvenience. They 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 hybernate, 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 evolution of the seasons in warm climates; 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; exhibiting an admirable adaptation to the peculiar condition 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 some species are capable of flight. Von Meyer, an eminent German naturalist, has therefore arranged the fossil reptiles into groups, characterised by the organs of motion;* as *flyers*, *swimmers*, or *walkers*. From this general view of the economy and habits of the recent reptiles, we shall be able to comprehend the physical conditions required by those extinct forms which occur in a fossil state, and thus arrive at some interesting

* Palæologica zur Geschichte der Erde und ihrer Geschöpfe Von Meyer. See a translation of a portion of this work, "On the Structure of the Fossil Saurians," by G. F. Richardson, Esq. (Mag. of Nat. Hist. vol. i. p. 281,) of the British Museum.

conclusions respecting the regions which they inhabited.

28. TURTLES.—In turtles the want of active faculties is compensated by their passive means of resistance. They have no weapons of offence, but are inclosed 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, 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 class of reptiles appears to be from 54° N. lat. to about 40° S. lat.* The fluviatile species of tortoise, or *emys*, 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*,

* 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.

which inhabits the hot regions of America. They live upon food which is found stationary at the bottoms of rivers; in the stomachs of several procured from the Ganges, Col. Sykes found large quantities of muscles, the shells of which were broken into small angular fragments; and I have fossil bones of a trionyx (*T. Bakewelli*) from Tilgate Forest, imbedded in a mass of shells of the same genus; a collocation which might be expected in a fluviatile formation. 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 their respective genera.

29. FOSSIL TURTLES.—The remains of turtles are among the earliest indications of the reptile tribe, and occur in the new red sandstone. The impressions of their feet, or pats, are seen in the quarries of that rock, in Dumfriesshire; and entire tracks of these prints are preserved on the surface of the stone; "one slab exhibits twenty-four continuous impressions of feet, forming a regular track, with six distinct repetitions of the marks of each foot, the fore-foot being different from the hind-foot: the appearance of five claws is discernible in each fore-paw."* The remarks on the rippled sandstone of the wealden (page 356), and on the impressions of human feet in stone (page 76), in the previous lectures, render it unnecessary to explain this phenomenon. In the lias and oolite,

* Dr. Duncan.

remains of this family have been found; the wealden contains marine, land, and freshwater species; and the chalk several marine turtles; bones of a trionyx have been found in the Kentish chalk, by Mr. W. H. Bensted. In the tertiary deposits, both marine and fresh-water turtles occur: they are associated with the Sivatherium in the Sub-Himalayas—with the mastodon in the Burmese Empire—with palæotheria in France—and with fruits and tropical plants in Sheppey; their bones and eggs are daily becoming imbedded in the recent conglomerate of the Isle of Ascension (page 78).

30. Crocodiles.—This family contains the only living reptiles that approach in magnitude to the colossal forms of the fossil kingdom. The Egyptian crocodile, or alligator, is known to attain a large size; and the rivers of India are inhabited by *gavials* of enormous bulk, sometimes nearly thirty feet in length. The gavials are distinguished by the great length and slenderness of the beak, or muzzle. The nature of the teeth of these animals, and their mode of increase and renovation, have already been described (page 385). The vertebræ, or bones of the back, are convex behind, and concave in front, fitting into each other, like a ball and socket; a construction rarely found in the fossil species. Almost all the vertebræ of crocodiles from the wealden, are either flat or slightly concave at both extremities; and this character prevails, not only in the fossil animals of this family, but also

in those of the lizard tribe. A crocodile, nearly twenty feet long, has been discovered in the lias of Yorkshire; teeth of crocodiles have been found in the Stonesfield slate; two species of gavial in the Kimmeridge clay of Havre, by M. Alexandre Brongniart; and two species in the lias of Wirtemberg, by Dr. Jaeger. Species of several related genera occur in the oolite and Jura limestone. The wealden affords two or three species; the chalk an equal number; the tertiary strata of the London basin, one species with concavo-convex vertebræ; and similar remains abound in the newer pliocene deposits of North and South America, the Sub-Himalayas, &c. Neither the iguanodon, megalosaurus, hylæosaurus, ichthyosaurus, or plesiosaurus, have ball and socket vertebræ. This peculiarity of the vertebral column is very remarkable, and seems to indicate some general condition of the earth during the secondary period requiring such a modification of structure in the reptile tribes.* This family of reptiles, like the testudinata, extends through the vast periods of the secondary and tertiary eras to the present time. As the crocodiles frequent fresh-water, and not the sea, their remains testify the existence of regions watered by streams and rivers.

31. ICHTHYOSAURUS, (*fish-like lizard.*)—In the lias of the west of England, bones and teeth, supposed to belong to crocodiles, had for many years

* Appendix M.

excited attention; but until 1814, when a considerable collection, from Dorsetshire, formed by Miss Mary Anning, was exhibited in London, no accurate investigation of these interesting relics had been attempted. Subsequently a great number of bones and skeletons have been found, numerous memoirs published, and the form and structure of the originals thoroughly investigated, by Mr. König, Sir E. Home, Cuvier, Conybeare, De la Beche, and Dr. Buckland. Many extraordinary specimens are figured and described in the splendid work of Mr. Hawkins, whose unrivalled collection of these remains is deposited in the British Museum.* The bones and skeletons so abundant in the lias are chiefly referable to two genera; the one called the *ichthyosaurus*, by Mr. König, to denote its relation

TAB. 93.—RESTORED FIGURE OF THE ICHTHYOSAURUS.
(*From Mr. Hawkins.*)

to fishes and reptiles; the other, *plesiosaurus*, so named by Mr. Conybeare, to mark a nearer approach to the lizards, or saurians, than the animals of the other genus.

* Memoirs of Ichthyosauri and Plesiosauri; by Thomas Hawkins, Esq. F.G.S. Folio, with 28 Plates. Relfe and Fletcher, London.

The ichthyosaurus had the beak of a porpoise, the teeth of a crocodile, the head and sternum of a lizard, the paddles of cetacea, and the vertebræ of fish. This restoration (Tab. 93) shows its general configuration. There are eight or more species, some of which attain 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 mode of regeneration; one species has 110 in the upper, and 100 in the lower jaw. 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 very strong and largely developed, and those of the sternal arch offer a remarkable correspondence with those of the sternum of the *platypus*, of Australia.

Like turtles, the animal had four paddles, composed of numerous bones enveloped in one fold of integument, so as to appear an entire fin, as in the cetacea; the fore-paddles are large, and in some species are formed of one hundred bones; the hind are smaller, and contain but thirty or forty (Tab. 94.) The internal structure of these instruments,

* Dr. Buckland.

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—a *humerus*, *radius*, *ulna*, and *phalanges*.

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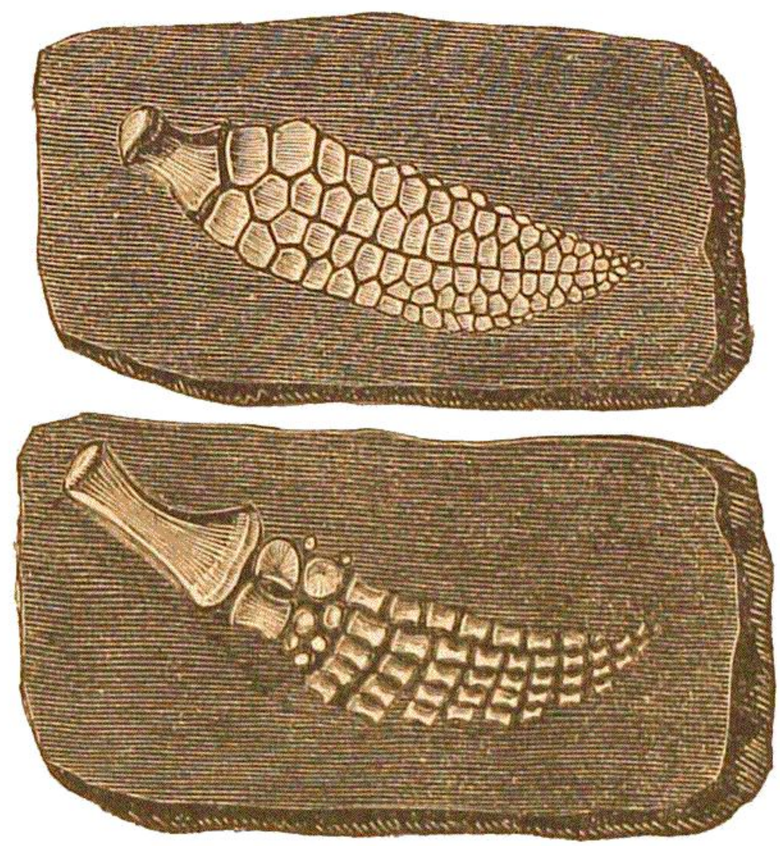


2

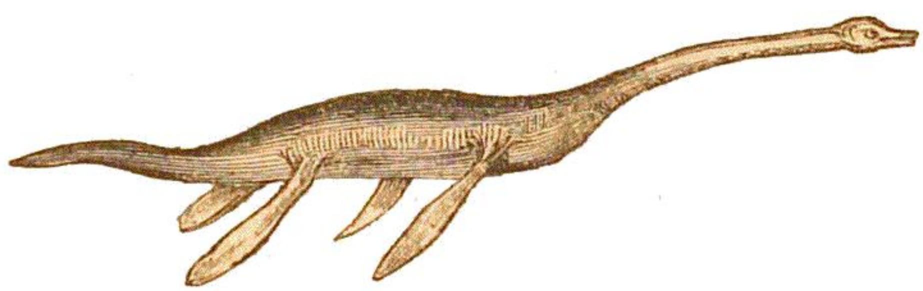
TAB. 94.—PADDLES OF THE ICHTHYOSAURUS AND PLESIOSAURUS, IN LIAS SHALE, FROM LYME REGIS.

Fig. 1. Left fore-paddle of the ichthyosaurus.
Fig. 2. Left fore-paddle of the plesiosaurus.

(One-eighth the natural size.)

The nostrils, which in crocodiles 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 spinal 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, having four large fins or 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 interior of the skeleton, that it was an inhabitant of the sea. Its skin appears not to have been covered with scales.†

32. THE PLESIOSAURUS.—The discovery of a remarkable specimen, by Miss Anning, enabled Mr. Conybeare to establish the character of that



TAB. 95.—RESTORED FIGURE OF THE PLESIOSAURUS.
(*From Mr. Hawkins.*)

extraordinary creature, the plesiosaurus, which differs from the ichthyosaurus in the extreme smallness

* Memoir on a peculiarity of structure in the neck of the ichthyosaurus; by Sir P. M. de Grey Egerton, Bart.

† The *epidermis*, or scarf-skin, and the *corium*, or true skin, occur in a fossil state.—Dr. Buckland, Plate 10, Fig. A. 1, 2, 3, 4.

of the head, and enormous length of the neck; the latter is composed of upwards of thirty bones, a number far exceeding that of the cervical vertebræ in any other known animal. This reptile combines in its structure the head of a lizard, with teeth like those of a crocodile, a neck resembling the body of a serpent, a trunk and tail of the proportions of those of a quadruped, with paddles like those of turtles. The vertebræ are longer and less concave than those of the ichthyosaurus, and the ribs, being connected by transverse abdominal processes, present a close analogy to those of the cameleon. Six or more known species of plesiosauri have been determined.

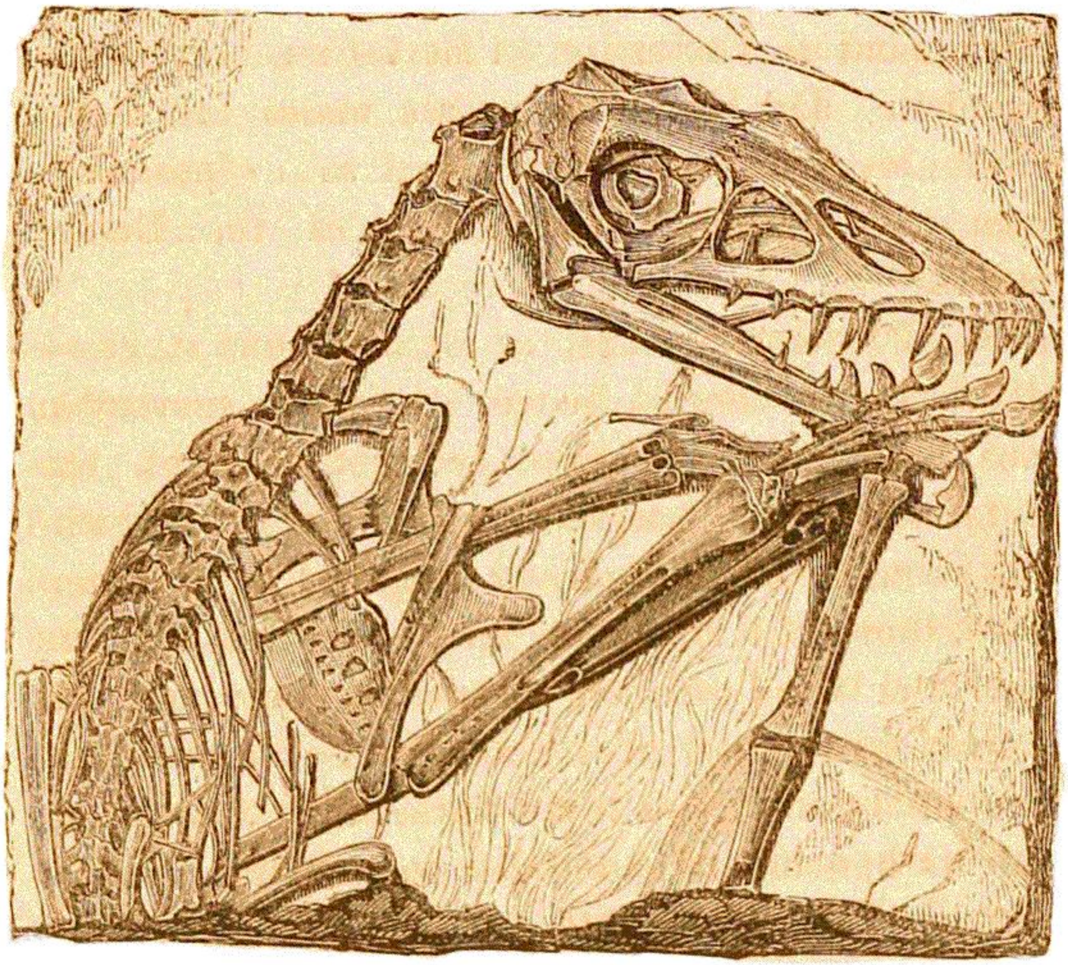
The collection of Mr. Hawkins, now in the British Museum, contains a skeleton eleven feet long, and so nearly perfect, that the form of the original creature may readily be traced. Mr. Conybeare compares the plesiosaurus to a turtle stripped of its shell, and thinks it probable, from its long neck presenting 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 fishes on which it preyed.

Ichthyosauri and plesiosauri have been found throughout the secondary strata, from the lias to the chalk inclusive; Lyme Regis, owing to the researches of Miss Anning, is the most celebrated locality in England, but they also occur in the lias of other parts of Dorsetshire, and of the adjacent counties. Their remains have been discovered in the oolite both of this country and of the continent. I have found vertebræ of the plesiosaurus in the green sand of Faringdon in Berkshire, and in the wealden. Dr. Harlan describes bones and teeth, which he refers to ichthyosauri and plesiosauri, from the secondary formations of the United States.*

33. PTERODACTYLES, OR FLYING REPTILES.—Of all the wonderful beings which the researches into fossil osteology have brought to light, the pterodactyles are unquestionably the most extraordinary. With a head and length of neck resembling those of a bird, the wings of a bat, and the body and tail of ordinary mammalia, these creatures present an anomaly of structure as unlike their fossil contemporaries, as is the duck-billed platypus, or ornithorhynchus of Australia, to existing animals. The skull is small, with very long beaks, which extend like those of a crocodile, and 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 fore-finger is immensely elon-

* Medical and Physical Researches; by B. Harlan, M.D Philadelphia. A list of the known species of ichthyosauri and plesiosauri, with their localities, is given by Mr. de la Beche; Geological Manual, page 365.

gated for the support of a membranous expansion as in the bat: impressions of the web and of the membrane of the wing are seen in some specimens (Tab. 96). The fingers terminated in long hooks,



TAB. 96.—SKELETON OF A FLYING REPTILE, IN SLATE; FROM SOLENHOFEN.

(Pterodactylus crassirostris, Goldfuss.)

One-third the natural size.

like the curved claws of the bat. The size and form of the foot, leg, and thigh, show that the pterodactyle was capable of perching on trees, and of standing firmly on the ground, where, with its wings folded, it might walk or hop like a bird.* This stuffed specimen of an enormous bat, from the museum of the late Mr. Brookes, will serve to convey some idea of the fossil animal; I would here observe, that the wing of the bat is not merely an instrument for flight, but that 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. Eight species of pterodactyles have been discovered, and these vary in size from that of a snipe to a cormorant. At Solenhofen the bones of pterodactyles are associated with the remains of *libellulæ*, or dragon-flies;† and in the Stonesfield slate they are collocated with the *elytra*, or wing-cases, of beetles. The remains of a species of the size of a raven, discovered in the lias of Lyme Regis by Miss Anning, to whose talents and indefatigable researches British Palæontology is so deeply indebted, have been described and elucidated by Dr. Buckland ‡: this specimen is in the British Museum.

Numerous thin delicate bones, evidently belonging to pterodactyles, have been found in the Wealden,

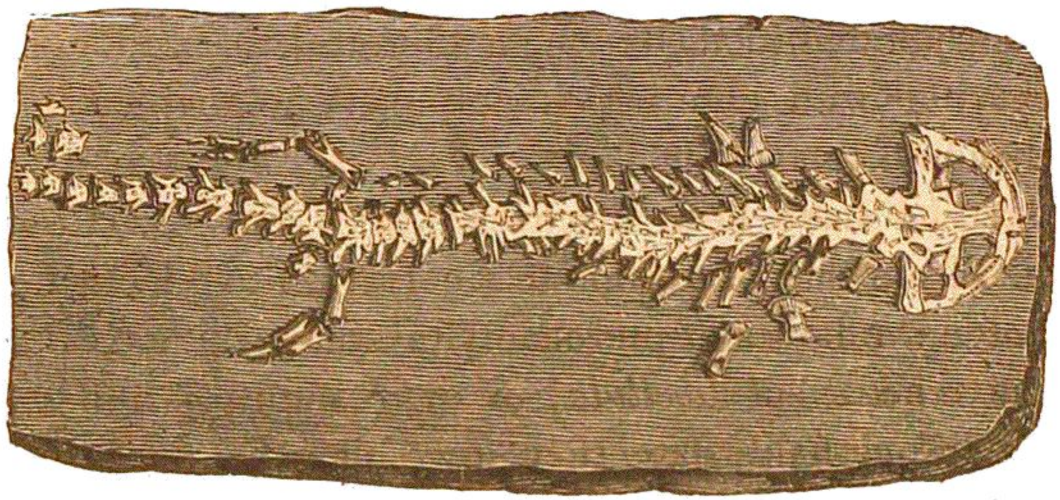
* Dr. Buckland. Mr. Martin has introduced a restored figure of the pterodactyle in the foreground of the Frontispiece of this work.

† Goldfuss.

‡ Geological Transactions, vol. iii. page 220.

and afford proof that those extraordinary creatures inhabited the country of the iguanodon.

34. FOSSIL SALAMANDER.—Fossil remains of toads, frogs, and salamanders, have been found in some of the newer tertiary strata. The quarries of Œningen, that yielded the fossil fox, mentioned in a former lecture (page 250), have also afforded



TAB. 97.—FOSSIL SALAMANDER OF ŒNINGEN.
"HOMO DILUVII TESTIS" OF SCHEUCHZER.
(Four and a half feet in length.)

specimens of the batrachian family of reptiles. The most celebrated relic of this kind is one which a German physician of some note, Scheuchzer, in 1726, declared to be a fossil man.* Cuvier, however, has ascertained that it is the skeleton of a gigantic, extinct, aquatic salamander; a fine portion of the skeleton of the same species, from Œningen is in the British Museum. It is worthy of remark, as a proof how prejudice may blind us to the most

* Philosophical Transactions, vol. xxxiv.

obvious truths, that Scheuchzer, although a physician, and therefore conversant with human osteology, could yet so grossly deceive himself as to believe that the fossil bones were those of a man; he describes the specimen, in an essay entitled "*Homo Diluvii testis*", as being indisputably the moiety, or nearly so, of a human skeleton, and states that the bones, and even substance of the flesh, are incorporated in the stone; and that it is a relic of that "cursed race which was overwhelmed by the deluge!"

35. FOSSIL REPTILES ALLIED TO THE LIZARDS.—The iguanodon, 100 feet in length, to which the iguana, but one-twentieth of the magnitude, is the only recent species that bears any affinity, has been described in a former lecture (page 389). The megalosaurus, whose remains occur both in the Stonesfield slate and in the wealden beds, has also been cursorily noticed. This creature partook of the structure of the crocodile and the monitor, and is computed to have attained a length of from forty to fifty feet. The teeth of the megalosaurus are (Plate III. fig. 9) flat, pointed, and curved backwards in the form of a pruning-knife; the inner edge is deeply serrated (Plate III. fig. 9*) down to the base; while the outer has a similar mechanism, but a short distance from the point. These teeth show that the animal was highly carnivorous. I am compelled to pass over other interesting peculiarities of structure presented by the fossil remains

of this enormous terrestrial reptile of the ancient world.*

In the magnesian conglomerate of Durdham Downs, near Bristol, three distinct species of fossil saurians, related to the iguana and monitor, have lately been discovered by Dr. Riley and Mr. S. Stutchbury. But I cannot enlarge on this or other notices of fossil saurians; for so numerous have been the recent discoveries of reptilian remains, that a bare enumeration of the essays that have been published on the subject would encroach too far on the limits of these lectures.†

36. Review of the age of reptiles.—From this examination of the organic remains of the secondary formations we arrive at the following results:—that the seas, lakes, and rivers, during the geological epoch termed secondary, were peopled by 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 terrestial inhabitants belonging to the tertiary

* See Dr. Buckland's Essay, page 235.

† Consult Cuvier's Recherches sur les Ossemens Fossiles, tom. v.;—Pidgeon's Translation of the Fossil Animal Kingdom, 1 vol. 8vo. 1830;—and Dr. Buckland's Essay; which contains a fund of instruction of the highest interest, conveyed in the most engaging style.

or present eras: throughout the vast accumulations of the spoils of the ancient islands and continents, although the remains of crocodiles, fresh-water turtles, insects and terrestrial plants abound, jaws of small animals related to the opossum 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 of the elk—of the palæotheria, or of other mammalia that were their contemporaries; the osseous remains of terrestrial or fluviatile reptiles alone appear. Here then, in the 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 abondait 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."*

We have seen that in the carboniferous limestone, the lowermost or most ancient of the formations in which reptiles occur, turtles and several genera related to the lizards have been discovered; in the lias, swarms of the extinct marine reptiles, the ichthyosauri and plesiosauri, with turtles, crocodiles, and pterodactyles; in the oolite, the megalosaurus, and several new genera allied to the crocodile, and two genera of *mammalia;* in the wealden, the *igua-*

* Oss. Foss. tom. v.

nodon, *hylæosaurus*, and other related genera, and *one genus of birds*. Thus the fauna of the secondary epoch, as established by its organic remains, presents the following characters :—

Mammalia ..	Two genera of marsupial animals.
Birds	One species of wader. Supposed impressions of the feet of several species.
Reptiles..	Marine—about twelve genera, including thirty or more species. Fluviatile and terrestrial—ten genera, with twenty species. Flying—one genus, eight or nine species.
Insects ..	Several species of libellula, and some coleopterous and neuropterous insects.

If we admit, to the utmost extent, the effect of causes that can be supposed to have operated in the exclusion of mammalian remains from the deposits under investigation, still the overwhelming preponderance of the reptile tribes, both on the land and in the waters, is most striking. But does this remarkable phenomenon support the hypothesis which some geologists have advanced, that during the secondary epoch the earth was not adapted to 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 to warm-blooded animals, and that its atmosphere was incapable of supporting the higher types of organization? The proof that birds existed in the country of the iguanodon—that marsupial animals inhabited the region of the megalosaurus and pterodactyle—that trees and plants, related to genera which now grow in territories abounding in mammalia, flourished in the dry land of that ancient epoch, are facts which appear to me fatal to such a hypothesis, and show that the physical condition of the earth, seas, and atmosphere was not essentially different from that of the tertiary and modern periods.

That reptiles predominated throughout the secondary epoch, to a degree far beyond what has since prevailed, cannot, by any legitimate process of reasoning, be disputed; but I do not think we are yet in possession of the data by which the problem can be solved.

37. OBJECTIONS CONSIDERED.—There are some who, with one of the Bridgewater essayists (Mr. Kirby *), 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 vege-

* Seventh Bridgewater Essay. Mr. Kirby supposes there is a subterranean world of reptiles, where the iguanodon still flourishes!!! and that the occurrence of a vertebra of the ichthyosaurus in diluvial gravel is 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 the antidote both before him.

tables in the ancient deposits; while there is not a river, or even 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; no where 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, certain 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 mean to assert, that reptiles, and reptiles only, were the occupiers of every island and continent; but I have shown, by 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 no example. I am ready to acknowledge that the proposition is somewhat astounding, and I do not feel much surprise that many intelligent persons hesitate to admit its correctness; but you have seen that it is deduced from such an immense accumulation of facts, 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 described would prove to be utterly untenable.

38. 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 those 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 man, is incompatible with the evident design of the Creator, and derogatory from the dignity of the human race, to whose pleasures and necessities all things were rendered subservient, and for whom alone they were created. But this assumption is utterly at variance with what we know of the living world around us; every where

we see forms of animated existence, possessing faculties and sensations wholly dissimilar to our own; and while, in the beautiful language of Scripture, we are told that not a sparrow falls to the ground without our heavenly Father's notice, the contemplation of the present constitution of nature, by any philosophical observer, 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, 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 the inexpressible felicity which, in a higher state of existence, may be our portion, 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 writer*—"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

* Bulwer.

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 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 to us the sublime truth—*that for innumerable ages our globe was the abode of myriads of living forms of happiness, enjoying all the blessings of existence, and which at the same time were accumulating materials to render the earth, in after ages, a fit, temporary abode, for intellectual and immortal beings!*

LECTURE VI.

1. Introductory remarks. 2. Organic and inorganic kingdoms. 3. Distinctive characters of animals and vegetables. 4. Nervous system, and sensation. 5. Diversity of animal forms. 6. Ellis's discoveries. 7. Nature of sponge. 8. Cilia, or vibratile organs. 9. The hydra, or fresh-water polype. 10. Zoophytal organization. 11. The food of zoophytes. 12. Mode of increase and death. 13. Corals, or skeletons of zoophytes. 14. Diversity of form and structure. 15. Geographical distribution of the polyparia. 16. The flustra, or sea-mat. 17. The vesicular corallines, or sertulariæ. 18. The gorgonia, or sea-fan. 19. The red coral. 20. The tubipora, or organ-pipe coral. 21. Madrepores. 22. The actinia, or sea-anemone. 23. Caryophyllia and turbinolia. 24. Fungia. 25. Astrea, pavonia, &c. 26. Meandrina cerebriformis, or brain-coral. 27. Appearance of the living corals. 28. Coral reefs. 29 Coral reef of Loo Choo. 30. Coral islands. 31. Fossil zoophytes. 32. Zoophytes of the chalk. 33. Zoophytes of the Shanklin sand. 34. Recent formation of chalk from corals. 35. Fossil infusoria. 36. Corals of the oolite and lias. 37. Corals of the older secondary formations. 38. Coralline marbles. 39. The crinoidea, or lily-shaped animals. 40. Encrinites and Pentacrinites. 41. Structure of the crinoidea. 42. The lily encrinite. 43. Pear encrinite of Bradford. 44. Pentacrinites, actinocrinites, and other crinoidea. 45. Derbyshire encrinital marble. 46. Geological distribution of the crinoidea. 47. Concluding remarks.

1. Introductory remarks.—The secondary formations reviewed in the last discourse presented a marked increase in those extraordinary types of animal life — the polyparia, crinoidea, and other zoophytes. We observed that some deposits, as the *Coral rag* of the oolite, consisted almost wholly

of corals; while in the lias and other strata the mineralised skeletons of the lily-shaped radiaria were not less abundant. As we advance to the more ancient rocks, we shall find that the remains of these animals prevail in the older secondary strata, almost to the exclusion of other zoophytes; that entire mountain chains are composed of the consolidated *debris* of corals; and vast beds of limestone and marble, of the petrified skeletons of crinoidea. That we may understand the nature of these deposits, and be enabled to arrive at accurate conclusions as to their formation, a knowledge of the structure and habits of the existing animals is necessary; I therefore purpose devoting the present discourse to the consideration of the natural history of the recent and fossil corals, and of the lily-shaped animals.

2. ORGANIC AND INORGANIC KINGDOMS.—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 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 exist-

ence; if I break off a crystal from this mass, the specimen does not lose any of its properties, it is still a mass of crystals as before; but if a branch be removed from a tree, or a limb from an animal, both are rendered imperfect, and the parts removed suffer decomposition,—the branch withers, and the animal matter 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.* But

* 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 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 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, 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 the period of 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 particles prepared in appropriate organs, and transmitted by 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 particles, and preserves them in their new situations, but is

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*, p. 171.

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 subject 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. Distinctive characters of 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 the animal and vegetable kingdoms, 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

* Dr. Fleming. Philosophy of Zoology, 2 vols. 8vo.

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 determine with 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, we might 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 obvious distinctions which exist between animals and vegetables in their chemical composition, and in the form and distribution of their vessels. I must content myself with mentioning the more important character which animals alone possess, namely, the faculty

of SENSATION, communicated to animal matter by a nervous system. When any object comes in contact with my finger I am sensible of its presence, and my finger is said to possess sensation; but if I compress, or cut across the nerve which passes from the brain to the finger, 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, may be detected; and in the animals of the higher orders, nervous filaments can be distinctly traced, from their origin to their distribution in the various parts to which they communicate sensation. But in proportion as the system of absorbing, secreting, and circulating vessels, becomes less, a corresponding diminution takes place in the nervous fibres, till at length both the vessels and nerves elude our finite observation, and we are left to infer from analogy, that, since sensation depends on the presence of nerves, and the smallest animals evidently possess sensation, a nervous system exists in the minutest monad of animal organization.

In the largest and most perfect examples of the vegetable kingdom, 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 that faculty which in animals we term sensation.

But the nerves not only bestow feeling, they also confer the power of voluntary motion; and, if the construction of the organs to which such nerves proceed be suitable, *they enable the animal to* effect progression, or in other words, give it the faculty of changing 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 animals are inhabitants of the water.

Such, *then*, are the essential characters of animal existence—an external determinate form, gradually developed, with an internal organization possessing circulating 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.—The form is as varied in figure and magnitude as the imagination can conceive; from the god-like image of man, to the shapeless mass of jelly that floats upon the wave—from the elephant and the whale, to the insect and the animalcule, of which five hundred 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 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 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. Ellis's discoveries.—It was in this town (Brighton), in the year 1752, that Ellis first ascertained the animal nature of several of the small zoophytes which abound on our shores. It appears

that this eminent naturalist was engaged in forming a collection of marine plants for the instruction of the young princesses in botany, and having occasion to examine some of the specimens through a powerful microscope, he was astonished to find that the sponges, which were then supposed to be marine plants, possessed a system of vessels through which the sea-water circulated; and that many of the corallines exhibited pores, from which tentacula or feelers were constantly protruding, and then suddenly retracting, as if seizing and devouring prey. Subsequent observations have confirmed his opinion, 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 compound animal, but which are so minute as to elude our observation.

7. NATURE OF SPONGE.—This simple form of animal existence approaches so nearly to that of plants, that it will be instructive to dwell a few moments on the investigation of its structure. 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. 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 the small 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 most extraordinary nature, by which currents are produced in the fluid, and propelled in the direction required by the economy of the animal.

8. Cilia, or vibratile organs.*—Although these organs, which are termed *cilia*, or hair-like instruments, are not confined to the class of animals which form the subject of this inquiry, yet, as they play so important a part in the economy of the zoophytes and crinoidea, it will be necessary to define their structure and functions; and I shall avail myself of the highly interesting remarks of my friend Dr. Grant, and of Dr. Sharpey, on this subject, as well as on the anatomy and physiology of the polyparia, hereafter to be noticed.† The cilia resemble very minute hairs, and are only visible with the microscope; they are situated in

* From *cilium*, eye-lash.

† On the Nervous System of the *Beroë pileus*, Zoological Transactions, vol. i. p. 10. Outlines of Comparative Anatomy,

parts habitually in contact with water or other fluids, and possess the power of vibrating with great celerity, by which they produce motion and currents in the surrounding fluid. When a drop of water containing infusoria is brought under the microscope, it is seen that as these animals 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 as fins to assist the animal in progression; and when it 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, but may be considered as fringes of delicate hair, 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 observa-

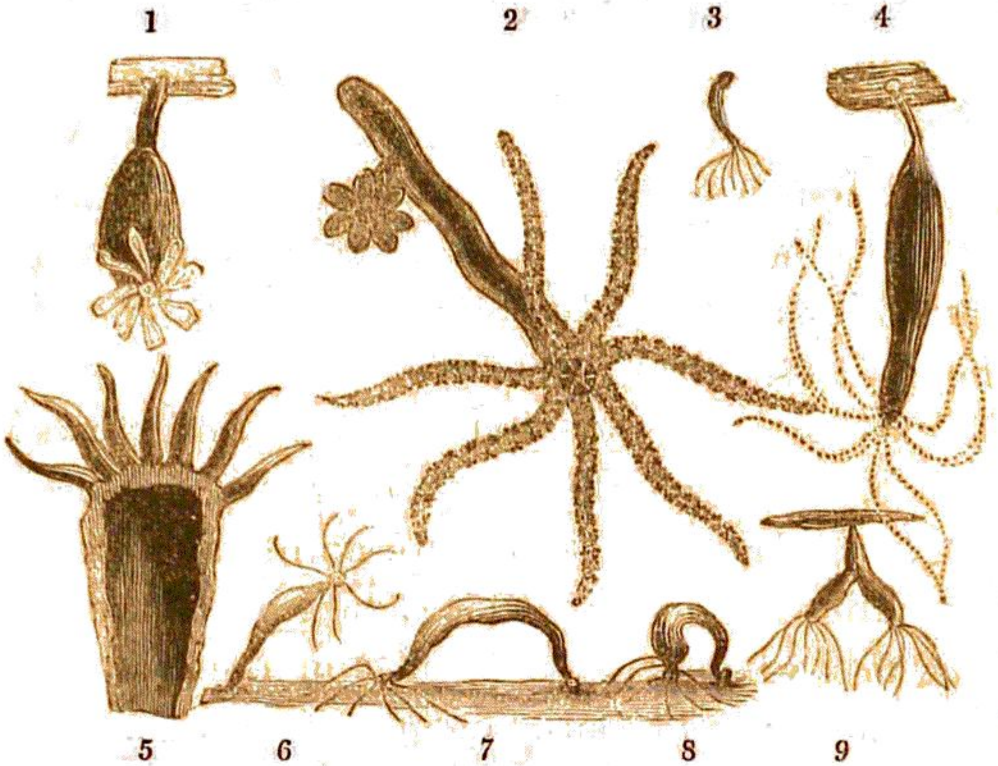
by Robert E. Grant, M.D. F.R.S. Professor of Comparative Anatomy at the London University.

See the article *Cilia*, by Dr. Sharpey; Cyclopædia of Anatomy and Physiology.

tion. In the simpler forms of animals, the cilia are the organs for motion, respiration, and the obtaining of food; they move with great regularity and velocity, and are exceedingly numerous. Dr. Grant has calculated four hundred millions of them on a single flustra foliacea! and ascertained their existence in the sponge; the currents which incessantly flow into the pores of that substance, being produced by the vibrations of the cilia attached to the inner surface of the tubes.

9. THE HYDRA, OR FRESH-WATER POLYPE.—In the hydra, or fresh-water polype (Tab. 98, fig. 3), that inhabits our ponds, ditches, and rivulets, we are presented with a highly organized structure, but of the simplest possible mechanism; 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 filaments or tubular tentacula. It is in fact a stomach, or digestive apparatus, with no appendage but the instruments for seizing its prey. A vertical section of the animal (Tab. 98, fig. 5) highly magnified, shows the interior of the receptacle for the food, the relative thickness of its substance, and the manner in which the tentacula are formed by an extension of the upper margin. This creature, perhaps the most simple form of animal life, 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 itself at pleasure. These enlarged drawings (Tab. 98) of the polypes in different states of contraction and motion,



TAB 98.—FRESH-WATER POLYPES.

(*Drawn by Miss Ellen Maria Mantell.*)

Fig. 1. Hydra fusca magnified, the tentacula partially expanded. 2. Two hydræ on the same tube, 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 polype.

will render a detailed description unnecessary. 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 animal can greatly elongate its body (as is shown in fig. 2), and, on the other hand, can contract its filaments, and shrink itself into a minute globular mass.

These animals are very voracious, and feed only on living animalcules, which they seize and secure by their tentacula. The marvellous power which the hydræ possess of bearing all kinds of injuries and mutilations with impunity, is well known. In whatever manner the animal be divided, the injured or lost parts are repaired, or reproduced; and if cut into pieces, every piece becomes a perfect animal. If the body be 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! * This examination of the structure and economy of the hydra will prepare us for the investigation of those more complicated forms of zoophytes which possess calcareous supports or skeletons, and form the more immediate subject of this discourse. The continuance of the ciliary motion in parts separated from the rest of the body, and even for some time after death, proves

* M. Trembley, of Geneva, in 1740, first observed the structure and economy of the fresh-water polype or hydra. Consult Dr. Roget's Bridgewater Essay; and Dr. Johnston's British Zoophytes, 1 vol. 8vo. 1838: a work of high interest, and evincing great talent and research.

that the action is independent of the will of the animal.

10. ZOOPHYTAL ORGANIZATION.—If we extend our observations to the patches of white calcareous matter, called *flustra*, that may be seen on every sea-weed or shell on the shore (Pl. V. fig. 6), appearing like delicate lace-work, we shall discover that these apparently mere specks of earthy substance, also belong to the animal kingdom. Many species of this zoophyte are common along our coasts, and I will describe their structure somewhat in detail, as their examination will serve to illustrate the nature of those corals which, from their magnitude and extent, become such important agents in the economy of nature.

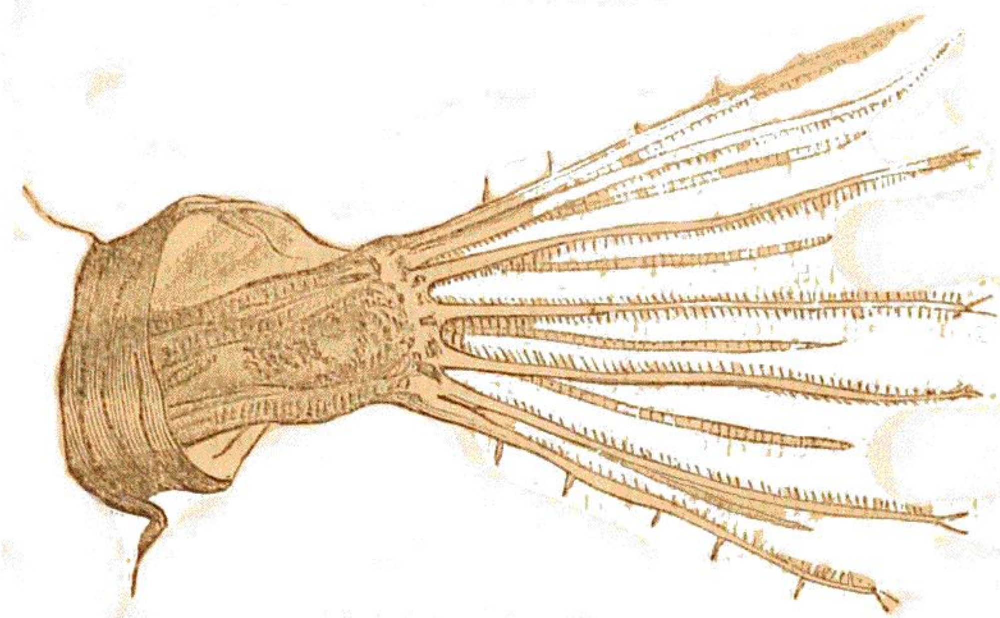
The flustra, when taken fresh and alive out of the water, presents to the naked eye the appearance of fine net-work, coated over with a glossy varnish; with a glass of moderate power, this substance is discovered to be full of pores, disposed with much regularity (Pl. VI. fig. 6). If a powerful lens 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: these expand, then suddenly close, withdraw into the cells, and again issue forth; the whole surface 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 connected by one common integument.

The surface of the flustra, viewed with a lens, (Plate VI. fig. 6,) exhibits a series of cells, symmetrically arranged, their forms and dispositions varying in the different species. When highly magnified, each cavity is seen to be the receptacle of a polype,* which appears like a transparent gelatinous mass, having a stomach or sac, the external margin of which terminates in eight or ten feelers or tentacula, that have the power of extending and retracting with great rapidity. A still higher power discovers that these tentacula are in many zoophytes furnished with the cilia or vibratory organs previously described; and the existence of similar instruments is inferred in the minute species where they have not yet been detected, because these atoms present the same phenomena of currents as the larger polyparia. The appearance of the polypi, in various states of expansion and contraction, is shown in these sketches (Pl. VI. figs. 3, 9), after drawings made by Mr. Lister, from observations on living specimens, carried on during a short residence in this town, (Brighton,) in 1832.† The animalcules were kept

* 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.

† The Philosophical Transactions for 1834 contain a memoir on the structure and functions of the tubular and cellular polypi, by J. L. Lister, Esq. F.R.S., in which are detailed the results of his observations made at Brighton.

alive by an ingenious contrivance, that secured a constant supply of fresh sea-water, without which they speedily perished, probably from want of food. The microscope, which was of unrivalled excellence, was so adapted that the polypi were kept constantly within the field of view, and I had the pleasure of witnessing the phenomena which I am about to describe.



TAB. 99. — POLYPE OF FLUSTRA PILOSA; WITH ITS MOUTH AND CILIATED ARMS PROTRUDED FROM THE CELL.*

(*Magnified* 150 *times.*)

Sometimes the polype was seen protruding its tentacula (as in Tab. 99, and Plate VI. fig. 3); in other examples, the animals retreated into their cells, and appeared in different states of contraction (Plate VI. fig. 9). In a specimen of *Campanularia* (Plate V. fig. 2), the animalcules were expanded in one branch, and retracted within their cells in the

* Lister. Philos. Trans. for 1834. Plate XII. fig. 2.

other. In the former instance, the tentacula were spread out, and numerous currents of water, evidently produced by the vibrations of the cilia, were seen rushing towards the centre. By these eddies the invisible beings which constitute the food of the polypi were brought within the vortex; the tentacula then closed, seized the prey, and conveyed it to the sac or stomach.

11. THE FOOD OF ZOOPHYTES.—However improbable it may appear to the mind unaccustomed to investigate the works of the Creator, that beings so minute as those under examination should prey upon living forms of yet more infinitesimal proportions, *the fact is nevertheless unquestionable. It is* even possible to select the food of animalcules much smaller than the polypi of the flustra, and thus exhibit their internal structure! The animals called *monads*, may be considered as the lowest limit of animated nature, so far as is cognizable by man, their diameters varying from the twelve hundredth part of an inch to the *twenty-four thousandth;* and the powers of the microscope at present extend no farther. These creatures are of a cylindrical or spherical form, having a mouth by which their nutriment is taken in, and a stomach or digestive apparatus: the latter is visible only when these living atoms are fed with colouring particles, the animals being transparent and colourless, and their natural food equally so. Dr. Ehrenberg, of Berlin, by furnishing these infusoria with colouring matter for

nourishment, has been able to illustrate their organization in an extraordinary degree. He employed a solution of pure indigo for this purpose; and the results of his experiments are highly interesting. Immediately on a minute particle of a very attenuated solution of indigo being applied to a drop of water containing some of the pedunculated *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 animalcule, and the particles of indigo are seen 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 beautiful phenomenon, than presently the body of the animal, which was before quite transparent, becomes 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

* The *Vorticellæ*, rotiferæ, or wheel-polypi, as they are commonly termed, from the supposition that they have organs which move round like a wheel, have cilia disposed in circles, which seen in some directions, when moving with great velocity, appear like wheels.—*Encyclop. Anat. and Phys.* p. 607. A lucid account of these animals, and of the whole family of infusoria and polyparia, is given by Dr. Roget, in his Bridgewater Essay: a work of great labour and profound research.

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.

But although, as I have already stated, the monad, in the present state of our knowledge, and with the wonderful instruments which the ingenuity of man has constructed, is the lowest known term of organization, yet it is impossible to doubt that there are myriads of living forms concealed from our observation, some of which serve as food to these miniatures of life.* I may here observe that the structure of many of the animalcules is as varied and complicated as that of the larger, and to our imperfect conceptions, more important orders of animals.†

12. Mode of increase, and death.—To return to the flustra:—If our observations on the living polypi be continued for a sufficient period,

* "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.

† To those who feel desirous of pursuing this subject I would recommend the Natural History of Animalcules, by Andrew Pritchard, Esq. 1 vol. 8vo. 1834.

we shall at length perceive a small globule thrown off from the mass, and become attached to the sea-weed or the rocks: this is the germ of a new colony of this compound animal. As it increases in magnitude, the usual character of the flustra may be detected; and if the *fleshy* film be removed, a *spot of calcareous matter* is left attached. 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, and for which I am indebted to my friend Robert Hannay, Esq., is a fine example of this brittle species; when first in my possession, it was highly offensive from the emanations evolved during the decomposition of the animal matter. It is now a calcareous skeleton, with here and there portions of the shrivelled integument, and of course without any traces of polypi in the cells.

Let us now refer to our previous investigations, and inquire if the flustra present 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, susceptible of external impressions, and expanding and contracting 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 the animal possesses a nervous, and also a circulatory system for effecting nutrition and reparation. We find also that when the flustra is removed from the element in which it lived, the substance of which it is composed, like the flesh of the larger animals, undergoes putrefaction—in other words, that the creature dies—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 substance that formed its support or skeleton, and which like the bones of mammiferous animals, was secreted by the fleshy mass, alone remains.

13. Corals, or skeletons of zoophytes.—I would here particularly remark, that the stony matter or support of all zoophytes is formed by a similar process; the substances called corals being secretions from an animal substance by which they were permeated and invested, in like manner as the bones and nails in man are secreted by the tissues or membranes designed for that purpose, and acting without his knowledge or control. Nothing can be more erroneous than the common notion that the cells in the larger corals are built up by the polypi which are found in them, in the same manner as are the cells of wax by the bee or the wasp.

From what has been advanced, we perceive that the flustra is a compound animal, composed of an immense number of individuals united in one body, and consisting of a fleshy substance, secreting a calcareous skeleton, and studded over with cells containing polypi, which may be considered as foci of vitality, by whose agency the life of the whole mass is maintained. Whether these separate centres of life are susceptible of pain and pleasure independently of the whole, it may not be possible to determine; we have a living proof in the Siamese twins,* that even in our own species there may be an united organization with distinct 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. However this may be, we are at least certain that the Eternal has bestowed on these, as on all his creatures, the capacity and means of enjoyment. In truth, when observing the active movements of the polypi of the flustra, through the microscope of Mr. Lister, the beautiful remark of Paley,† on the happiness enjoyed by the lesser animals, came forcibly to my recollection, and I thought with him, that if any motion of mute creatures could express delight it was exhibited by the beings on which I was gazing: if they had intended to make signs of their happi-

* Philosophical Transactions for 1830, p. 177.

† Natural Theology.

ness they could not have done it more effectually, for they were sporting about in every direction, sometimes expanding like a flower, then suddenly closing and partially retreating, and again extending themselves to their extreme dimensions.

14. DIVERSITY OF FORM AND STRUCTURE.—In the flustra, then, we have the elements of zoophytal organization, and all the varied and extraordinary forms which 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; in others, constitutes hemispherical masses, having numerous convolutions on the surface somewhat resembling in appearance the brains of quadrupeds; and in some it forms an aggregation of tubes, terminating in star-like openings. 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 polypi; while in another, and numerous division (of which the common *sertularia* is an example), the skeleton is secreted by the *outer* surface

of the animal substance, and constitutes an external protection to the polypi. In another family, the *gorgonia* (Tab. 101), 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* (Tab. 102, fig. 3). Sometimes the skeleton is impressed with the cells, as in the madrepores; while in other species, as the red coral, the stem is smooth, and exhibits no traces of the peculiar structure of the animal. Yet amidst these almost endless 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 polypi.

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.*

* Experiments of Mr. Hatchett.

15. Geographical distribution of the polyparia.—I will first consider the geographical distribution of these singular beings; 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 greater number of the corals or polyparia are inhabitants of the ocean; many species prefer the immediate influence of atmospheric changes, and are seen on the rocks and plants which the tide leaves bare, 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 polyparia are rarely found in places exposed to violent currents; it is in the hollows of 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, the pliant branches bending to the 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 islands, as I shall hereafter describe.

The peculiarities in the distribution of these animals are not confined to the relative depths of the waters; 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. 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. From the depths of the ocean they elevate those immense reefs that may hereafter form a communication between the inhabitants of the

* Lamouroux.

temperate zones.* I proceed to notice a few of the principal forms of polyparia.

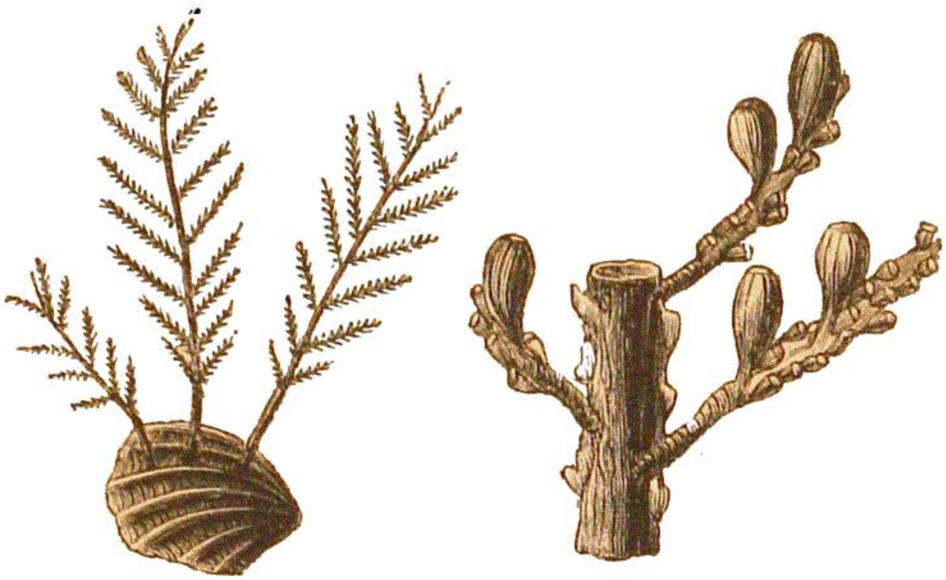
16. The flustra, or sea-mat. (Plate V. fig. 6; Plate VI. figs. 3, 9.)—The flustræ, as I have already remarked, present great variety of form, sometimes being attached to marine plants, which they inclose, as it were, in a living sepulchre (Plate V. fig. 6); at others, spreading into thin foliated expansions, which have both sides studded 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 profound 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, but 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

* Corallina; an excellent Abstract of Lamouroux's Memoir on the Flexible Corals. One vol. 8vo. 1834.

† Corallina, page 43.

polype the atoms necessary for its subsistence.* The flustræ are very abundant in a fossil state; there is scarcely an echinus of the chalk that has not several parasitical species attached to its shell.

17. SERTULARIÆ, OR VESICULAR CORALLINES. (Plate V. fig. 3.)—The elegant arborescent forms



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TAB. 100.—SERTULARIA, OR VESICULAR CORALLINE.

(*Sertularia nigra, Dr. Johnston.*†)

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

of the sertulariæ must be familiar to every one who has rambled by the sea-side. This branch of the sea-pine coralline (Tab. 100), which is shown magnified in this sketch (fig. 2), exhibits the usual

* Dr. Grant's interesting observations on the gemmules of the flustra are quoted by Dr. Roget, in his Bridgewater Essay, page 169.

† History of the British Zoophytes, page 129.

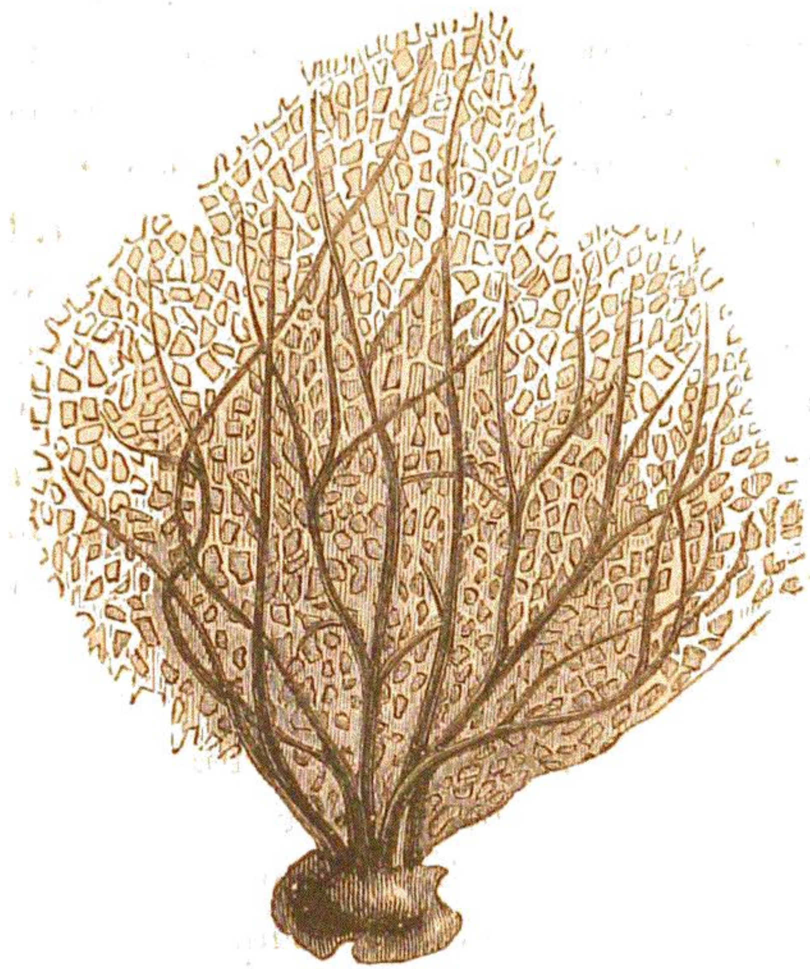
appearance of these corallines. The sertulariæ consist of tubes united together, and having lateral apertures for the protrusion of each polype; one elegant species, the *sertularia setacea*, is very abundant on the shores at Brighton after storms, being attached to the fuci and other sea-weeds. This representation of a branch magnified sixty times (Plate V. fig. 3) shows the form of the polypi, which, when fully expanded, are of great beauty. On one occasion, when I was present, Mr. Lister was observing a specimen of this creature, when a little globular animalcule swam rapidly by one of the expanded polypi; 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 hairs, that closed over the prey, which, after a few seconds, was carried slowly down, the mouth contracting, and the neck enlarging, into the stomach; here it was imperfectly seen, and soon disappeared.*

The *Campanulariæ*, so named from their bell-shaped cells placed on foot-stalks, are also abundant on our shores. Pl. V. fig. 2, is a magnified view of a branch of campanularia with several cells; in some the polypi are expanded, in others contracted. Viewed alive through the microscope,

* Philos. Trans. 1834, p. 372.

currents of minute globules are seen constantly running along the tubes, and are probably induced by the action of invisible cilia.

18. GORGONIA; SEA-FAN OR FEATHER.—The Gorgonia flabellum, or Venus's fan (Tab. 101), is



TAB. 101.—GORGONIA FLABELLUM.
(*One-twentieth the natural size.*)
Drawn by Miss Ellen Maria Mantell.

a flexible coralline, that is an inhabitant of 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, and of an external envelope or rind, which entirely invests the former. The gorgoniæ present great diversity of form and appearance. This specimen from the West Indies, (Pl. V. fig. 1,) is remarkable for its richness of colour, being a bright yellow, spotted with red; this species, (Pl. V. fig. 5,) 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 polypi disposed in two rows; a portion, highly magnified, is here represented, (Pl. V. fig. 1,) and exhibits several polypi 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 whence the polypi issue when the animal is alive; 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 you may observe in this branch of *Isis hippuris* (Tab. 102, fig. 3), in which a portion of the cortical part is removed, and the jointed 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 the seas of tropical climates. I believe but few traces of this genus have been found in a fossil state; a very beautiful species, however, occurs in the Maestricht limestone (Tab. 50, fig. 5).

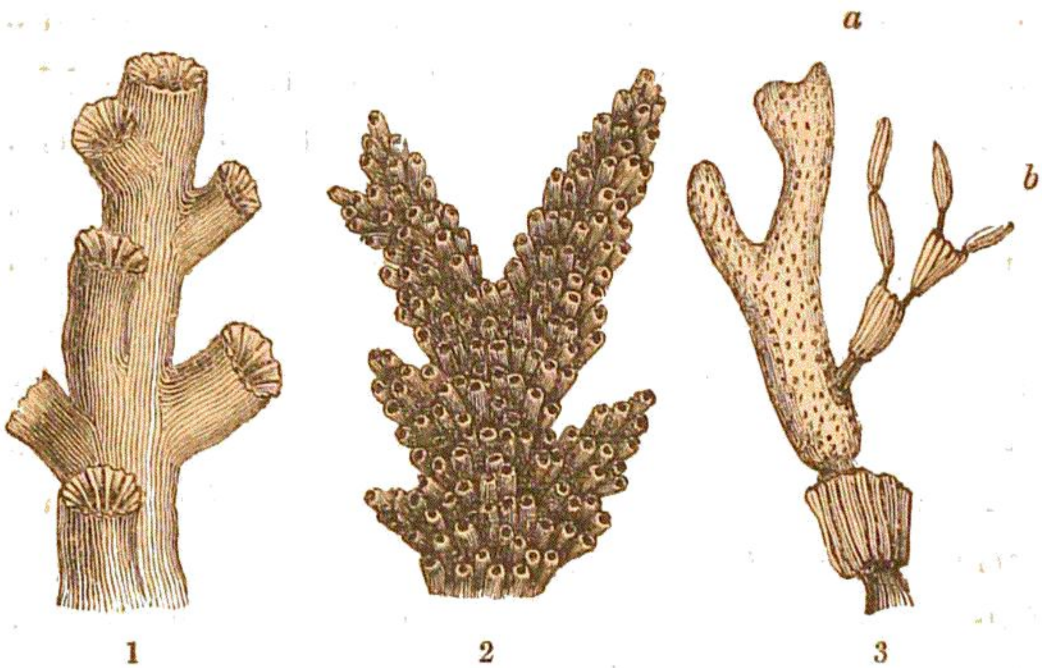
19. THE RED CORAL; *corallium rubrum*. (Pl. V. fig. 7.)—I advance to the examination of the polyparia whose axis is composed of a calcareous stony substance; and one genus of which possesses a skeleton of so beautiful a colour, and susceptible of so high a polish, as to be largely employed for purposes of ornament. 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, which is studded over with stellular polypi. This figure (Pl. V. fig. 7) represents a branch of coral with several polypi, highly magnified, as seen alive in the water. The cortical substance is removed from the extremities, and the red stony axis exposed. As the polypiferous centres only are composed of the animal crust which after death rapidly undergoes decomposition, no traces of their structure remain on the durable skeleton.

The red coral, as is well known, is so dense and compact as to bear a high polish; 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 polypi perish, their brilliant skeleton is exposed, and thrown upon the shore; the bright colour soon disappears, and the coral is reduced to fragments by the attrition of the waves, or, mixed with the remains of shells and other marine exuviæ: in this state it is thrown up by the tides, and being drifted inland by the winds, assists in forming those accumulations of the spoils of the sea which constitute many of the modern conglomerates described in a previous lecture (pp. 69, 77).

20. TUBIPORA; *Organ-pipe coral.* (Pl. VI. figs. 10, 12.)—This genus of corals is well known, from the elegance and beauty of one species (*Sarcinula musicalis*), 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. fig. 12;) in this manner large masses, consisting of a congeries of pipes or tubes, are formed. When the animal is 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 polypi; a magnified view, with a polype and section of two other tubes, is here represented (Pl. VI. fig. 10). This species occurs in great abundance on the coast of New South Wales, in the Red Sea, and in 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.



TAB. 102.—RECENT CORALS.

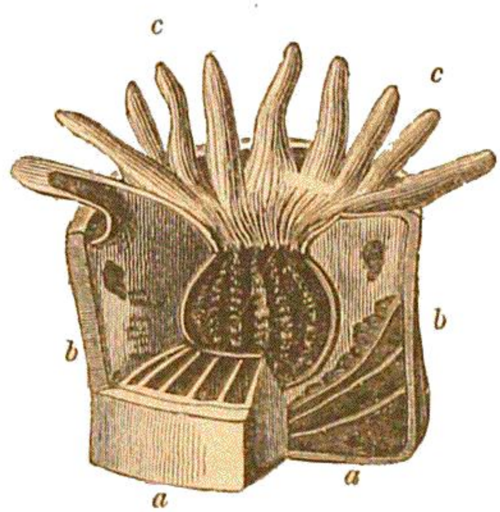
Fig. 1. A branch of Oculina ramea. 2. A branch of Madrepora muricata. 3. A branch of Isis hippuris; *a*, the cortical substance covered with pores which are the cells of polypi; *b*, a branch deprived of its outer covering, and exposing the articulated axis or stem.

21. MADREPORE (Tab. 102).—In the red coral, no cells are formed on the skeleton to serve as a protection to the polypi; but in the family of branched, or arborescent, calcareous polyparia, called *madrepores*, the little cups or cells, with radiating lamellæ, in which the polypi are situated, are composed of the substance of the skeleton. When the animals die, and the outer fleshy investment perishes, the axis is seen to be studded over with elegant, lamellated, stellular cells, variously formed and arranged, in different genera and species. In

some the cells are very distinct, as in this coral from the Mediterranean (*oculina ramea*, Tab. 102, fig. 1); in others they are exceedingly minute, as in this common species of madrepore (*madrepora muricata*, Tab. 102, fig. 2). The white branched corals, usually seen in collections, belong for the most part to this genus; it is not, therefore, requisite to describe this form of zoophyte more minutely. In the water the madrepores are invested with a fleshy integument of various colours; and each cell has a polype similar to those of the corals previously examined, and in the living madrepore a polype is seen to issue from each of the projecting cells, the branches being covered with their hydra-like forms.

22. THE ACTINIA, OR SEA ANEMONE. (Pl. VI. fig. 8.)—In another division of corals the cells are few, and of considerable dimensions, the polypi 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 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 often termed, appears, when quiescent, like a mass of tough jelly, of a sub-cylindrical form, and of various tints of crimson, green, blue, or brown (see Pl. VI. fig. 8); when expanded it presents a broad disk, surrounded by tentacula, having in the centre a corrugated sur-

face, 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 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



TAB. 103.—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.

the sac, or stomach, and afterwards ejected perfectly colourless, having absorbed the juices, and left the

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

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; a mechanism similar to that of the spiral appendages of the spirifera, described in the former lecture (page 474). 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 was desirous of shifting its situation, it distended one half of the body with water, then withdrew the base from the stone, and sunk to the bottom of the vessel in which it was contained. This plan (Tab. 103) of the internal structure of the actinia will serve to illustrate these remarks. The surface of the stomach, and even the internal lining of the tentacula, are abundantly furnished with cilia; the actinia has no durable skeleton.

23. CARYOPHYLLIA, TURBINOLIA, &c. (Pl. V. fig. 9; Tab. 50.)—In this small coral (*caryophyllia cyathus*) from the Mediterranean, and in this fossil from the chalk (Tab. 50, fig. 3), we have examples of an isolated calcareous cell, divided by vertical lamellæ or partitions, arranged in a radiated manner. This cell is the skeleton 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 *turbinolia* (Tab. 50, figs. 1, 2) possesses a similar structure.

In the caryophylliæ possessing more than one cell, each receptacle contains a polypus, as in the *caryophyllia angulosa*, (Plate V. fig. 9,) which is here represented as it appears when alive. In another genus, *pocillopora*, (Plate V. fig. 5,) the investing fleshy skin is beautifully mottled, and the polypi are terminal as in the caryophylliæ.

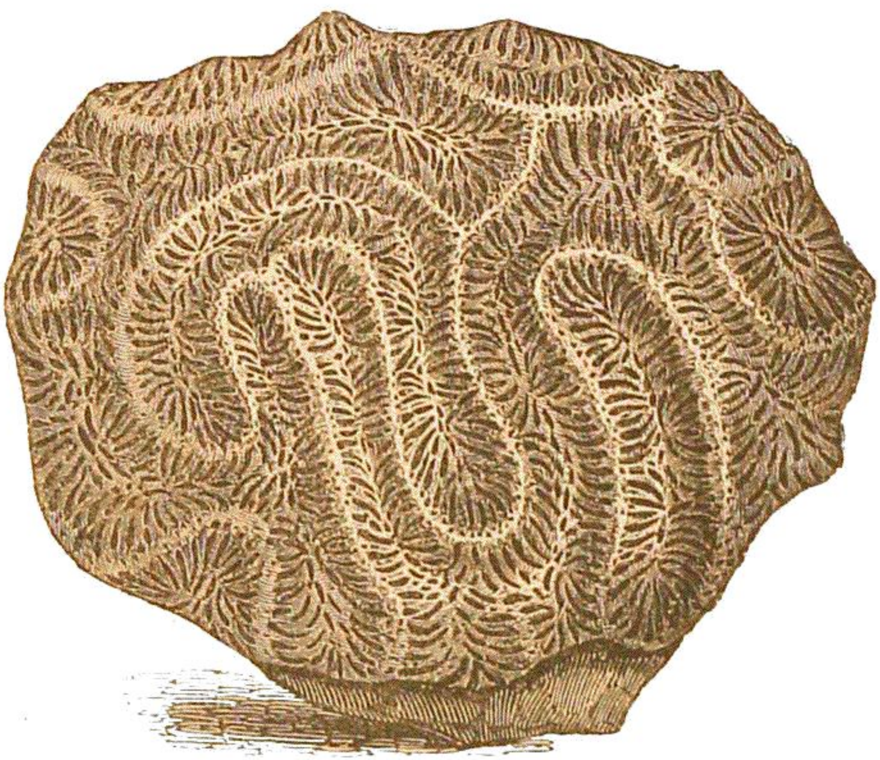
24. Fungia. (Plate VI. figs. 2, 4.)—The white, disciform, lamellated corals, called sea-mushrooms, or *fungiæ*, from their fancied resemblance to fungi, are among the most elegant forms of polyparia in the cabinets of collectors (Tab. 50, fig. 4). These, in a living state, are covered with a thick, transparent, jelly-like substance, which fills up all the numerous radiating interstices of the calcareous laminæ (see Plate VI. fig. 4); in the central depression the fleshy mass is formed into a large polype with tentacula; in the fungiæ, there is but one polype—but one focus of vitality. In *fungia actiniformis*, (Plate VI. fig. 2,) 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.

25. Astrea, pavonia, &c. (Pl. VI. figs. 7, 11,

13.)—In some of the large stony corals, the cells for the polypi 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. 11). The polypes in this species are of a dark-green colour, more than 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 polypi are seen expanded, and others contracted. In this magnified view, Pl. VI. fig. 7, of a single polype, the tentacula are shown in an expanded state, 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 polypi present the most diversified and vivid hues.

The *pavoniæ* 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. 13, represents a group of cells with polypi, of the ***P.** lactuca,* from the shores of the South Sea islands. The polypi are of a deep-green colour, and there is a connecting, transparent, fleshy substance, which extends over the extreme edges of the foliated expansion of this elegant coral. "From the magnitude and muscularity of the polypi in the 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 forms of the flustræ."*

26. MEANDRINA *cerebriformis;* or brain-coral. —The large hemispherical corals, whose surface is



TAB. 104.—BRAIN-STONE CORAL.

(*Meandrina cerebriformis.*)

covered over with meandering ridges and depressions, disposed in a manner that somewhat resembles the convolutions of the brain, are well known by the name of *brain-stone* (Tab. 104). In a living

* Dr. Grant's Comparative Anatomy.

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 sketch, (Pl. V. fig. 4,) shows the appearance of the coral in the water; the polypi are retracted and concealed. 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 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 lay 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* (page 48) vegetates, while the lower is entering into a mineral mass, in which the traces of organization remain when life has entirely ceased. In corals, in like manner, the more durable materials of the generation that has passed away, serve as the foundation over which their progeny spread successive accumulations of calcareous matter.

27. APPEARANCE OF THE LIVING CORALS.—In

* Principles of Geology.

some parts of the sea the eye perceives nothing but a bright sandy plain at 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 most celebrated parterres of the East.

Ehrenberg, the distinguished German naturalist, whose labours have so greatly advanced our knowledge of the infusoria, was so struck with the magnificent spectacle presented by the 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.

Instead of one lecture, many would be required fully to elucidate the natural history of the polyparía, so numerous and varied in appearance and structure are the modifications of this class of animal existence.

28. CORAL REEFS.—I have already alluded to the vast accumulations of calcareous rocks in tropical seas, resulting from the consolidation of the disintegrated skeletons of polyparia; but the physical changes that are produced by such apparently inadequate means require farther consideration, since they illustrate the formation of the coralline rocks, which will hereafter come under our notice.

In the flustra foliacea of our coast (page 526), 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 birth. 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, which 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 such detritus, as it shortly would be in its native element, 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 skeleton of the flustra of our shores may form the nucleus of a solid rock; and in the process I have described, we have, as it were in miniature, the formation of a coral reef.

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

30. CORAL ISLANDS.—Kotzebue, Flinders, and MM. Quoi and Gaimard, 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 polypi 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, 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, which is composed of shells and echini, with fragments of corals, united by calcareous sand, produced by the pulverization of the shells of 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 and insects. Even before the trees form groves or forests, sea-birds nestle there; strayed land-birds find refuge in the bushes; 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 the islands are ancient coral reefs, and these, in all probability, are based on the cones or craters of submarine volcanoes long since extinct. 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 a supply of water.

Of the grand scale on which the changes here contemplated are going on, 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.

There is so much of the marvellous and sublime in the idea of the creation of islands and continents by the ceaseless labours of numberless myriads of living instruments, that we cannot be surprised that this interesting subject has attracted the attention of one of the most elegant of our modern poets; I will relieve this detail by the following beautiful extract from the "Pelican Island," of 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,
Formed 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 weakest creatures in existence,
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,
Filled with dry mummies of the builder worms."

31. FOSSIL ZOOPHYTES.—Although many genera of polyparia are omitted in this brief sketch, I must pass without further comment to the consideration of the fossil zoophytes, of which, in this place, I purpose offering a cursory review. The formation of conglomerates, from the debris of corals and shells, has been fully explained in a former lecture (page 69). In the newer pliocene of Palermo many Mediterranean corals are imbedded. The blocks of silex, agate, and chalcedony, which are scattered over some districts in the West Indies, frequently contain meandrinæ, astreæ, and caryophylliæ, in a silicified state; and polished slices exhibit the internal structure of the corals in a highly beautiful manner, as may be seen in these specimens, presented me by the Hon. Mrs. Thomas, of Ratton, near Eastbourn. The Crag (page 206) abounds in flustræ, sertulariæ, and other genera of small polyparia, apparently of species that now inhabit the British seas. In the older tertiary the remains of turbinoliæ, caryophylliæ, astreæ, fungiæ, and of other genera, amounting to about thirty species, have been discovered.

32. ZOOPHYTES OF THE CHALK.—In the chalk formation the remains of this family occur in profusion. In the upper divisions, the Maestricht beds, the lamelliferous corals, as the astreæ, meandrinæ, fungiæ, (Tab. 50, page 307,) &c. prevail, and may be extracted from the friable arenaceous strata, in a fine state of preservation; the celluli-

ferous genera are not less numerous. In the white chalk the large calcareous polyparia are rare, while the fibrous zoophytes occur in profusion, both in the chalk and in the flints. Sponges of several kinds, and many species of allied genera, abound in every chalk-quarry in the south-east of England. One of the most common of the poriferous zoophytes, is a species which occurs either in an expanded state like a broad flat disk, or contracted into a cyathiform shape; the latter, when silicified, gives rise to flints, which from their forms have acquired the name of petrified mushrooms, or goblets, according as the cavity is either full or empty. I have, in the "Fossils of the South Downs,"* so fully explained the structure of the original, under the name of *ventriculite*, that it will here be sufficient to observe that the living zoophyte was of a cyathiform figure, and probably composed of a tough, jelly-like substance, capable of expansion and contraction. The smaller extremity was attached to the rock by root-like processes; the outer tissue consisted of a net-work of cylindrical, perhaps tubular, fibres, and the inner surface of the funnel-like cavity was studded with polypiferous cells or openings. Silicious specimens occur in every variety of shape which such a structure could assume; some are conical and hollow, others resemble fungi, many are turbinated, and not a few appear like a flat disk or plate; in all the margins

* Illustrations of the Geology of Sussex, p. 167.

are more or less impressed with undulating lines, which are produced by the section of the inclosed zoophyte.

The chalk also abounds in zoophytes which present a close analogy to the recent alcyonia; these are animals having a fleshy or gelatinous substance, invested with a tough outer skin, the surface of which is covered with pores, each pore being the cell or receptacle of a polype, as in the flustra. In this drawing of a portion of a common species of alcyonium (*alcyonium gelatinosum*, Plate V. fig. 8), highly magnified, six polypi are shown in various states of protrusion from their respective cells. The *dead men's fingers*, as the *alcyonium digitatum* is commonly named, has a similar structure.* The alcyonia are permanently fixed by the base, and possess the rudiments of a skeleton, for many species have acicular, silicious spines; hence the name of sea-nettles given to those varieties which wound or sting on being handled.

In the *choanite*, a fossil zoophyte common in the chalk, and which is called petrified sea-anemone by collectors, crucial spines, resembling those of the recent alcyonia, may be detected. The choanite is of a sub-cylindrical form, with root-like processes, having a cavity or sac which is deep and small, in comparison to the bulk of the animal. The inner surface is studded with pores, which are

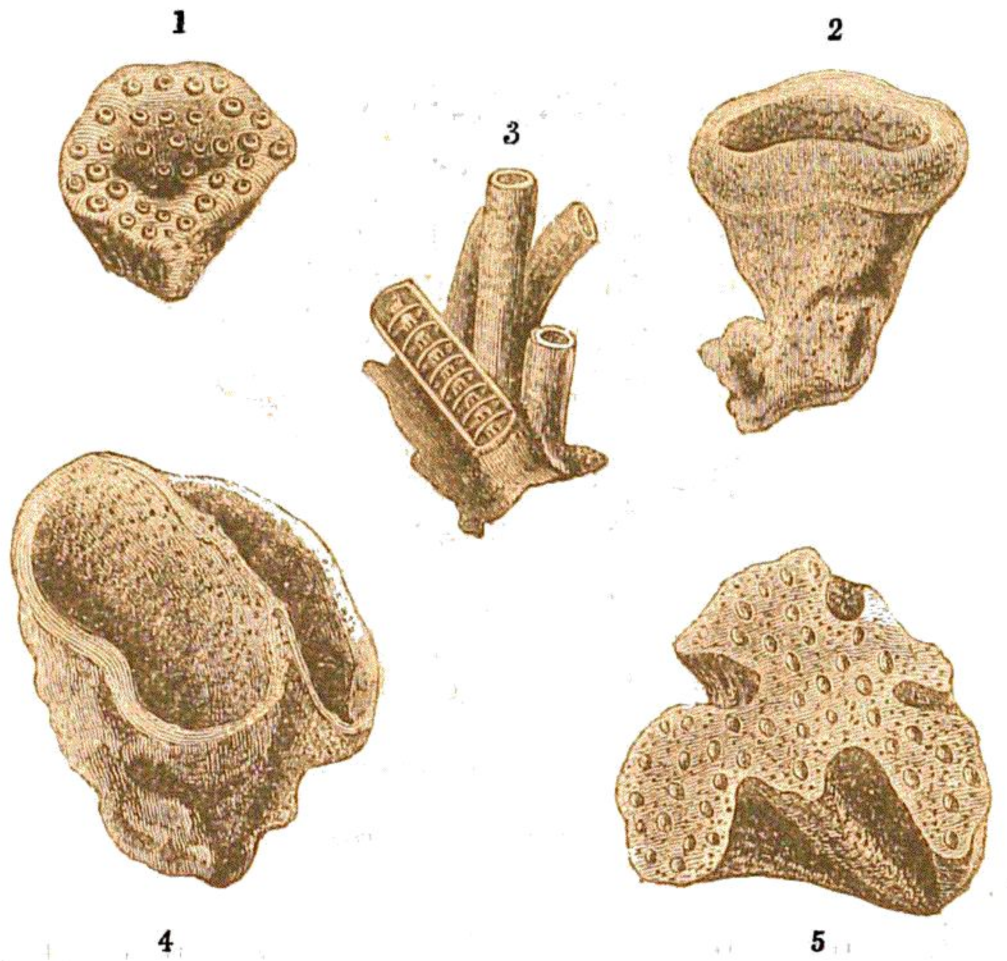
* See Dr. Johnston's beautiful and interesting work on British Zoophytes, Plate xxvi.

the terminal openings of tubes, disposed in a radiating manner, and ramifying through the mass. The beautiful markings observable in many pebbles, collected on the shores at Brighton and Bognor, are derived from the silicification of the internal structure of this zoophyte;* the horizontal sections display a central disk, from whence the tubes diverge to the circumference—the vertical exhibit an elongated conical space, probably the cavity of the stomach; in some examples this organ appears to have been furnished with lateral *cæca*, or pouches; and in all, small tubes are seen to permeate the mass. Ramose sponges form the nuclei of most of the irregular branched flints; and zoophytes related to other genera of poriferæ are equally abundant. A small species of caryophyllia (Tab. 50, fig. 3) occurs in the chalk of Sussex, and a turbinolia (Tab. 50, figs. 1, 2) in the galt.

33. ZOOPHYTES OF THE SHANKLIN SAND.—In the arenaceous strata of the chalk formation, the Shanklin sand, immense numbers of zoophytes, particularly of the poriferæ, prevail in some localities. The gravel-pits in the immediate neighbourhood of Faringdon, in Berkshire, are extremely prolific in these remains. The beds consist of an aggregation of sand impregnated with iron, with water-worn and pulverized shells and corals, and contain

* See Geology of the South-East of England, p. 106. "THOUGHTS ON A PEBBLE;" the frontispiece of this little work represents a pebble with a choanite inclosed.

myriads of perfect shells and polyparia, with casts of nautili and ammonites. The great mass of the materials is in the state of a friable conglomerate, but here and there indurated blocks occur. In a

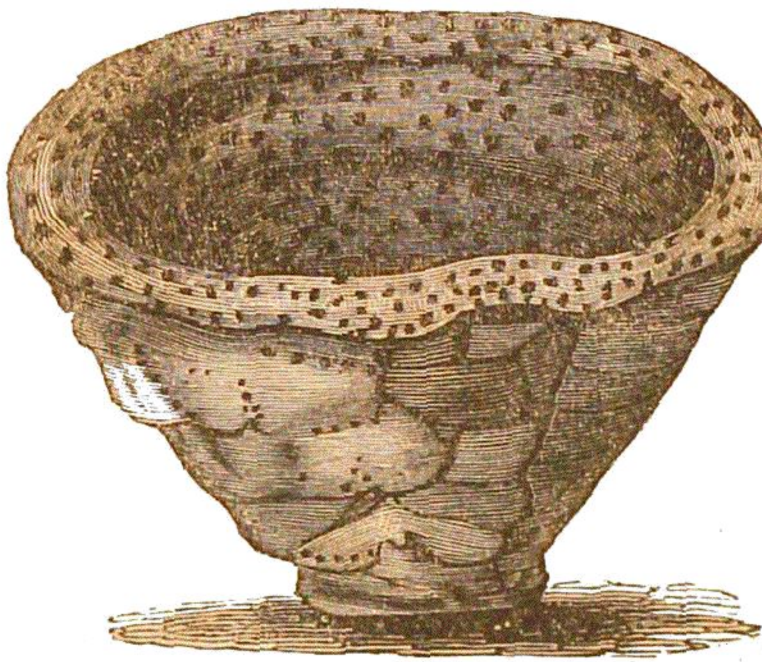


TAB. 105.—FOSSIL ZOOPHYTES FROM FARINGDON.

(*Collected and drawn by Miss Ellen Maria Mantell.*)

Figs. 1, 2, Manon peziza. 3. Tubipora anastomosans. 4. Manon. 5. Undescribed coral.

few visits to these quarries I collected numerous specimens of nautili, belemnites, ammonites, ostreæ, terebratulæ, echinites, and their spines; milleporæ, tubiporæ, and several minute corallines, with spongiæ, alcyonia, and many species of unknown or undescribed genera. One of the most abundant and perfect of the poriferæ of the Faringdon pits, is an elegant cyathiform zoophyte (Tab. 106), called



TAB. 106.—FOSSIL ZOOPHYTE FROM FARINGDON.

(*Chenendopora fungiformis.*)

by the quarrymen *petrified salt-cellar;* it is of a porous structure, and the inner surface is studded over with polypiferous cells, each of which, in a recent state, was filled by a polype.

The green and grey sand near Warminster, has yielded to the researches of Miss Etheldred Benett, of Norton House, (a lady, whose works have ably illustrated the Geology of Wiltshire,) many species of fibrous zoophytes, of which but few traces occur in the sands of Kent or Sussex.

In the Shanklin sand of the Isle of Wight, Mr. Webster discovered the remains of a species of *Syphonia*, which he called the tulip alcyonium.* The original appears to have resembled in shape a closed tulip, having a pyriform bulb or head supported by a long stem, with a broad base for attachment to the rock. Sections of the bulb display a congeries of longitudinal tubes, arranged somewhat concentrically, and these may be traced from the base and along the stem; similar remains have been found by Mr. Bensted in the Kentish rag, near Maidstone; these fossils are generally silicified throughout. A species of *syphonia* abounds in the silicious nodules of the chalk near Lewes and Brighton; and in one quarry, every flint contains vestiges of this kind of zoophyte.

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 characters 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 beds which may be

* *Syphonia pyriformis* of Goldfuss. Dr. Fitton's Memoir, Plate XV.

supposed to have been formed in the shallows, or near the shores of that ancient sea. About 150 species of zoophytes have been discovered in the cretaceous deposits; and in some localities entire strata of chalk are composed, like the modern calcareous beds of the Bermudas, of the detritus of polyparia.

34. Recent formation of chalk from corals.—In reference to the formation of coral limestones, I may too observe, that some beds of those deposits, in which the decomposition of the calcareous zoophytes is complete, consist of a pure calcareous mud, which when consolidated cannot be distinguished from chalk, as you may observe in the specimens before us, collected by Lieutenant Nelson. It appears from the observations of that gentleman, that on the shoals where these corals abound, the dead polyparia are continually decomposing, and the white mud thus produced is carried away by the waves, and deposited in the tranquil depths of the ocean. Mr. Darwin has also remarked a similar operation in the Pacific, where disintegration of the coral reefs and islands give rise to vast accumulations of a calcareous debris, which when dry closely resembles soft chalk.

In the Danish islands of Seeland and Möen, the flinty chalk is covered by beds of coral limestone, some portions of which form a compact building-stone, while others are a mere mass of corals cemented together by white chalk. These beds are shown by Mr. Lyell to belong to the chalk formation;

and although they abound in univalve shells not common in the cretaceous strata, yet a large proportion of the sponges, corals, echinites, and belemnites, are identical with those of the chalk. Mr. Lyell concludes "that the peculiarity of the fossil 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.†

35. FOSSIL INFUSORIA.—In the previous lecture (page 324), I noticed the occurrence of infusoria in the chalk flints; the subsequent microscopic investigations of Mr. Reade have shown that our flint nodules are almost entirely composed of the silicious skeletons of these infinitesimal beings, mingled with the shields of minute crustacea, the spines of alcyonia and other zoophytes, and the scales of fishes.‡ Among the most interesting of the specimens with which Mr. Reade has favoured me are two objects, which, although so minute as to be scarcely discernible by the unas-

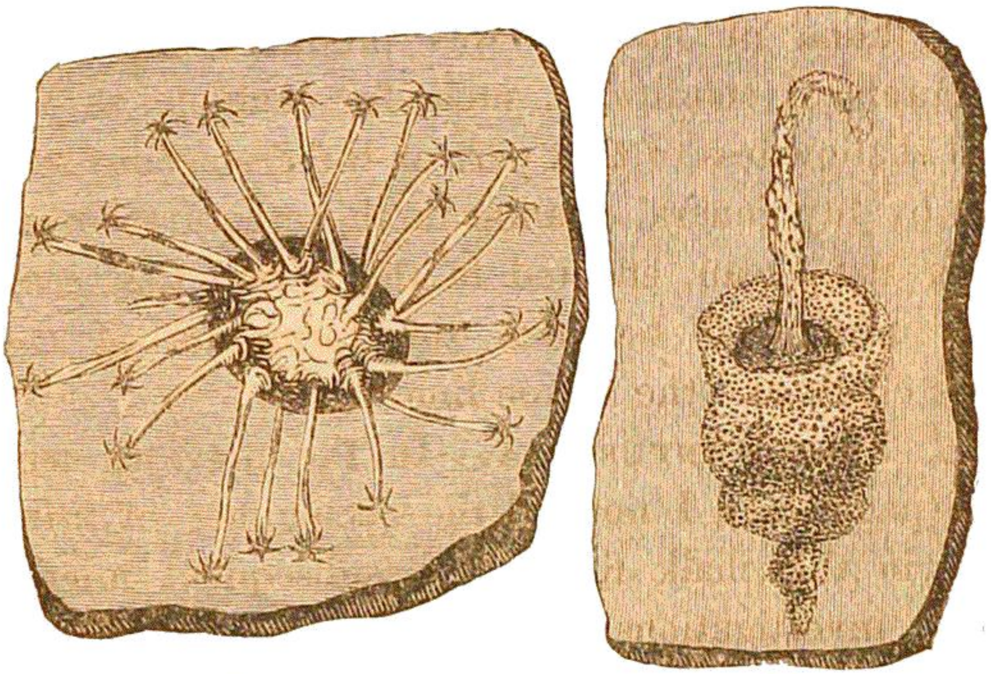
* In Denmark; the locality where these beds are best displayed.

† Mr. Lyell on the Cretaceous Strata of the Islands of Seeland, and Moen; Geol. Trans. Vol. V. new series.

‡ See "Observations on some new Organic Remains in the Flint of Chalk," by the Rev. J. B. Reade, M.A. F.R.S.—*Annals of Natural History*, No. ix. 1838.

sisted eye, the microscope displays to us as remains of the highest importance.

The drawings which I place before you (Tab. 107, figs. 1, 2,) represent these fossils magnified



1 2

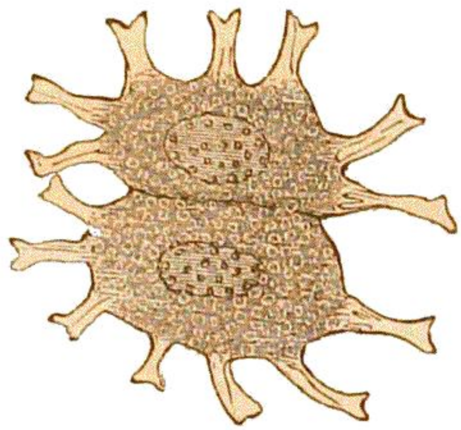
TAB. 107.—INFUSORIA AND ZOOPHYTE IN FLINT.

(*By the Rev. J. B. Reade.*)

Fig. 1. *Xanthidium tubiforme.* 2. Zoophyte with the polype protruded from its cell; *magnified* 500 *times.*

500 times linear. The specimen, fig. 2, you will at once recognise as the cell of a zoophyte with the polype protruded, the animal, like the fishes in the chalk (page 331), having been surrounded and entombed in the mineral matter, while alive and in activity; with the exception of the tentacula, which appear to have perished, the entire form and structure are preserved. The infusorial animal, fig. 1, is in a state of preservation equally

perfect. It closely resembles the recent *Xanthidia** (Tab. 108), which are animalcules having a silicious case or shield, beset with spines or tubes, which are exquisitely displayed in the fossil before before us.



TAB. 108.—XANTHIDIUM FURCATUM, a recent infusorial animal; *magnified* 300 *times linear.*

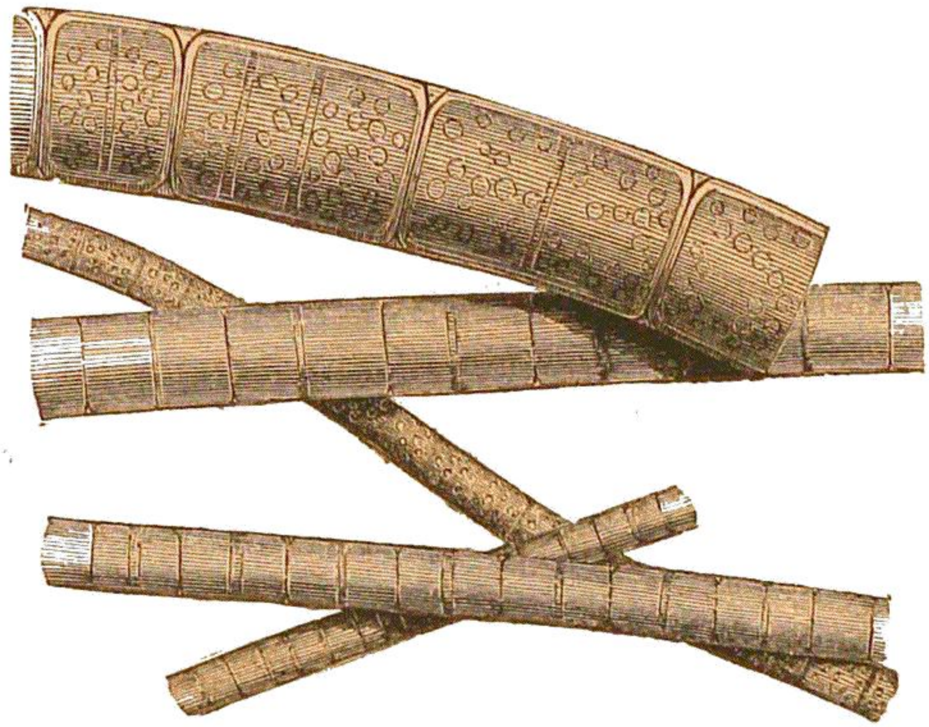
(*By the Rev. J. B. Reade.*)

The *Gaillonellæ* † are another family of infusoria whose remains abound in flint and opal, and which are so minute that forty-one thousand millions of their skeletons would occupy but a cubic inch. They consist of a simple silicious, cylindrical, or globose shield, arranged in a longitudinal series, appearing like a tubular chain, as shown in this drawing of some recent specimens (Tab. 109). These animalcules increase by self-division, and the chain-like appearance arises from the separation not being complete; their powers of reproduction are so

* See Appendix N.

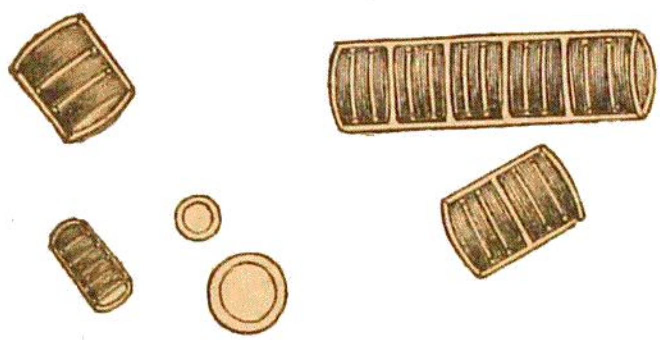
† Named from Gaillon, a French naturalist. See Appendix O.

great, that a single individual would yield 140 millions of millions in the course of twenty-four



TAB. 109.—RECENT GAILLONELLÆ; HIGHLY MAGNIFIED.
(*By the Rev. J. B. Reade.*)
Gaillonella varians.

hours. The separate, and connected gaillonellæ, as



TAB. 110.—FOSSIL GAILLONELLÆ; HIGHLY MAGNIFIED.
(*By the Rev. J. B. Reade.*)
Gaillonella distans.

they appear in a fossil state, are shown in this sketch (Tab. 110). When we consider that of the countless myriads of these animals,* that are as it were momentarily produced, every individual possesses an indestructible skeleton, it is easy to conceive how important an addition is made to the solid crust of the earth by this marvellous agency.

Many strata are entirely composed of the shields or skeletons of infusoria; and in Sweden an edible earth, resembling fine flour, and celebrated for its nutritious qualities, wholly consists of the shells of microscopic animalcules: this earth occurs in layers nearly thirty feet in thickness. Deposits of this kind are constantly in progress wherever a condition suitable to the economy of the infusoria exists. In lakes, marshes, and peat-bogs, the animalcules which inhabit the water pass through their brief period of existence, and their indestructible skeletons then sink to the bottom, and form new deposits. Professor Bailey discovered in a peat-bog in America, layers several hundred yards in extent of a white, earthy substance, which is wholly made up of the silicious shells of infusoria.† To silence all scepticism on this subject, Ehrenberg obtained considerable quantities of silicious earth from existing species of infusoria; and in which, by the aid of the microscope, the skeletons of the animalcules from which it was derived can be distinctly seen.‡

* Ehrenberg states that a corpuscule almost imperceptible, can become in four days 170 billions, or as many single individual animalcules as are contained in two cubic feet of the slate of Bilin.

† American Journal of Science, vol. xxxv. page 118.

‡ Annals of Natural History, No. III. page 131.

36. CORALS OF THE OOLITE AND LIAS.—The oolite, as I have previously remarked, abounds in corals, and contains beds which are decidedly 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 of the oolite presents all the characters of modern reefs; the polyparia belong to astreæ, 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 others by silicious infiltrations.* The corals, shells, &c. are of species not now known in a living state. Those who have visited the district 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 almost identical features presented by these rocks and the 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 that enormous series of

* At Tisbury, in Wiltshire, a beautiful silicified coral occurs, a polished section of which is represented, Tab. 111, fig. 9; no trace of the calcareous earth of the original remains.

deposits, the Oolite or Jura formation, which, as we have seen, extends over a great part of Europe, and has been formed in a vast sea, coral beds are not universally distributed, but occur only in certain localities; in other terms, they are found to occupy the situations which in their native seas presented the conditions required by their peculiar organization. The zoophytes of the oolite have yielded about 200 species, all of which are extinct.

In the Lias but few polyparia are preserved; and the saliferous system presents but three or four species of gorgonia, three of retepora, and one of astrea.

37. CORALS OF THE OLDER SECONDARY FORMATIONS.—The mountain limestone of the carboniferous system, which will be described in the next lecture, abounds in the cellular and lamelliferous zoophytes. In the Silurian rocks, entire beds are composed of the remains of polyparia; and a few species of corals constitute the last trace of animal organization in the crust of our globe.

The simple turbinated corals having, like the fungia, but a solitary cell, inhabited by one polype, occur in great abundance and perfection in the limestones of Dudley, which belong to the Wenlock formation* (Tab. 111, figs. 1, 3); a small species of fungia (Tab. 111, fig. 2), is also found associated with the immense mass of marine exuviæ of which those strata are composed.

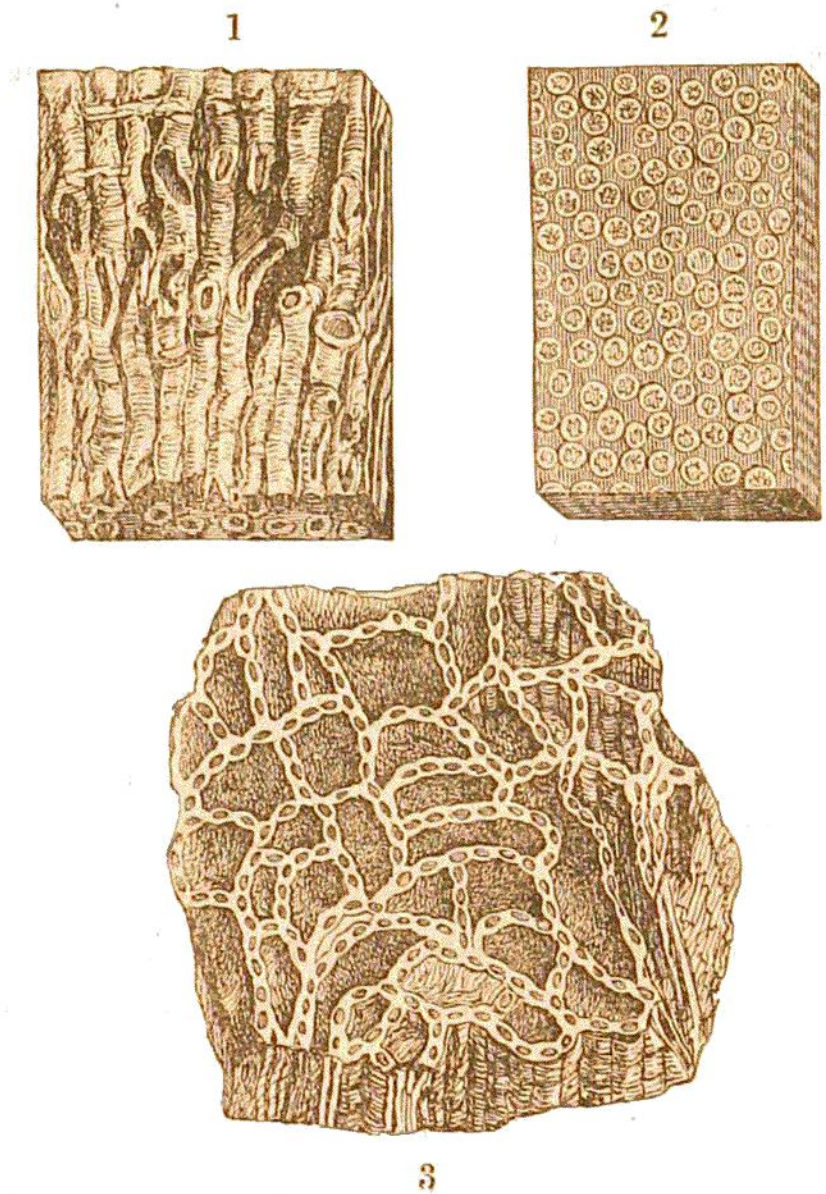
* Of Mr. Murchison.

The *tubiporæ* are among the earliest traces of organic bodies that are observable in the ancient

TAB. 111.—FOSSIL CORALS.

Fig. 1, 3. Cyathophyllum turbinatum. 2. Fungia. 4. The surface of cyathophyllum hexagonum. 5. Syringopora geniculata, of Professor Phillips. 6. Caryophyllia from the oolite. 7. Milleporite. 8. Cyathophyllum basaltiforme. 9. Columnaria oblonga, from Tisbury. 10. Coralline marble.

strata. Many of the limestones are an aggregation of an extinct species of this genus; and on masses long exposed to the weather * (Tab. 112, fig. 1), the structure of the original coral is sometimes well displayed, the tubes appearing in relief on the surface of the rock.



TAB. 112.—FOSSIL TUBIPORES AND CORALLINE MARBLE.

Fig. 1. Tubipore in Derbyshire limestone. 2. Marble composed of tubipores. 3. Chain-coral (catenipora labyrinthica) from Dudley.

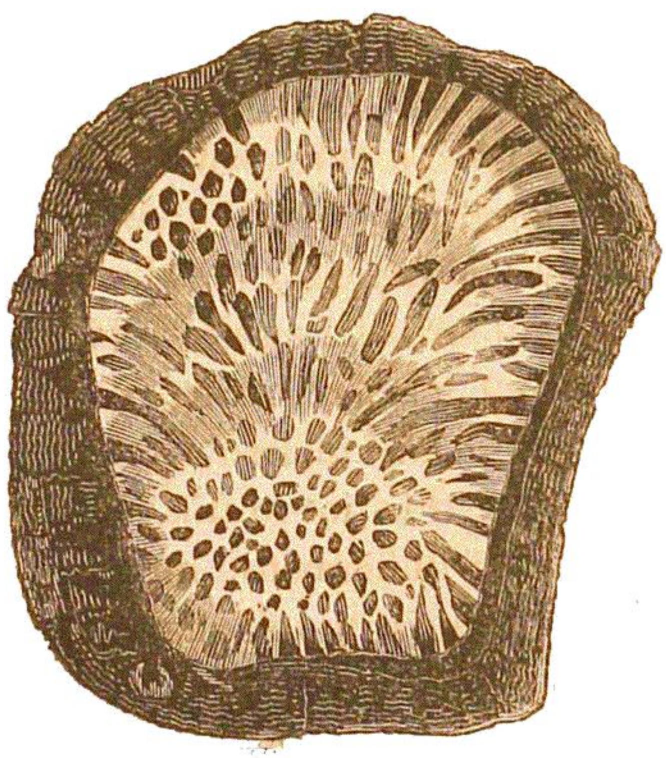
* I am indebted for specimens to Sir George Sitwell, Bart. and J. Meynell, Esq.

38. Coralline marbles.—A reddish marble, beautifully marked by the sections of the inclosed tubipores, and susceptible of a good polish, is quarried in some parts of Derbyshire (Tab. 112, fig. 2).

Mr. Parkinson has ascertained that the hue of this marble is dependent on the original colour of the coral, which, like the recent tubipore (page 540), was probably of a rich scarlet.

I have mentioned (page 530), that the earthy matter of the recent corals, like the phosphate of lime in the bones of animals, is formed by secretion from a membraneous structure, and that the lime may be removed by a chemical process, and the membrane 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 tissue can be detected. To my late friend, Mr. Parkinson, we are indebted for the knowledge of this interesting fact. He immersed a piece of tubiporitic marble (Tab. 112, fig. 2) in diluted 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 membraneous 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."

A curious form of tubipore occurs in the Dudley limestone, which from the appearance of the sections of the tubes, has received the name of chain-coral (Tab. 112, fig. 3). The tubes of this species are oval, and arranged perpendicularly side by side, in undulating lines; transverse sections, therefore, give rise to elegant markings on the surface, resembling delicate chain work. This tubipore is only found in the ancient rocks.



TAB. 113.—CARYOPHYLLIA, IN A POLISHED PEBBLE, FROM TORQUAY.

(*Drawn by Miss Jane Allnutt.**)

The pebbles that are thrown by the waves upon the shore near Torquay, on the coast of Devonshire,

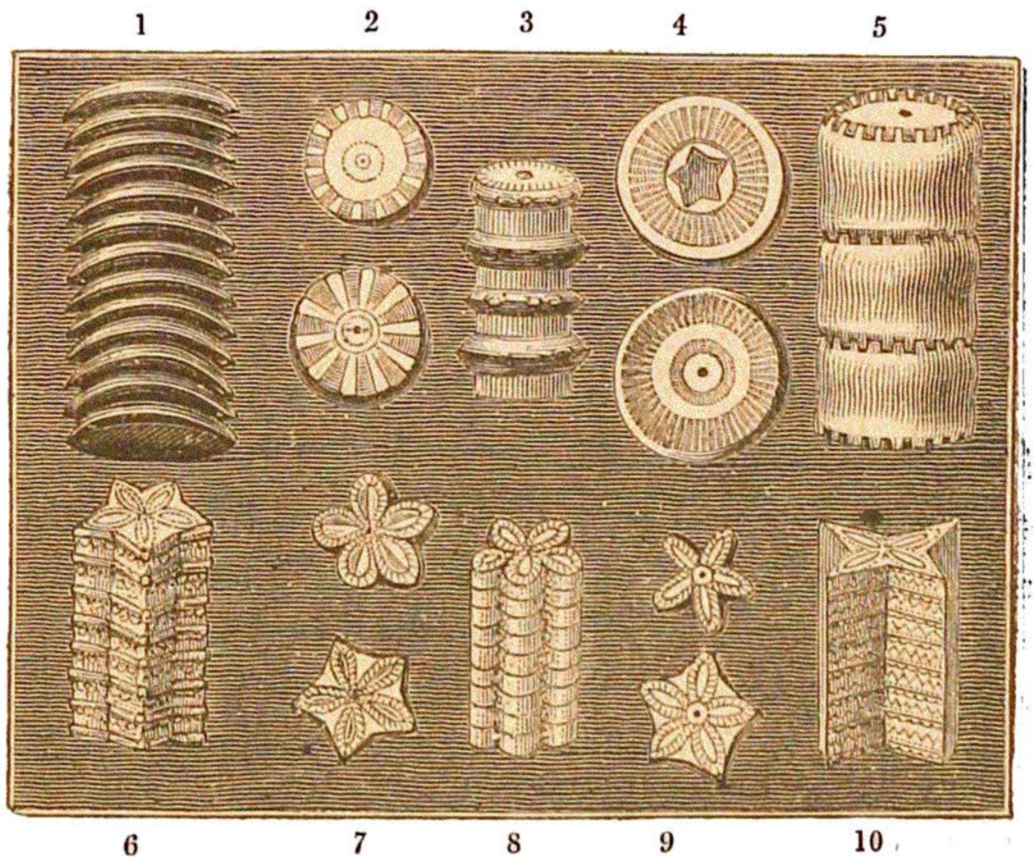
* From a beautiful specimen in the possession of Mrs. Allnutt, of Clapham Park.

and which are water-worn fragments of the limestones of the country, inclose caryophyllia, madrepores, and other corals; and when cut and polished exhibit sections which admirably display the structure of the original (Tab. 113).

The ornamental marbles of Babbicombe, Bristol, &c. owe their beauty to the inclosed zoophytes. The black Kilkenny marble, in such general use, is mottled with varied and elegant white figures, which are sections of fungiæ, turbinoliæ, caryophylliæ, and other corals, transmuted into opaque calcareous spar. Some of the markings appear like the nebulæ of comets, while others resemble lace-work, being sections of the reticulated structure of the cells of the polypi. I must not, however, dwell longer on this subject, but proceed to the examination of another class of animals, which, although not intimately related to the polyparia, it will be convenient to notice in this place, since their remains are found in immense numbers associated with those of corals, in the formations hereafter to be investigated.

39. The crinoidea, or lily-shaped animals. — The animals, whose fossilized remains, cemented together by carbonate of lime, form the Derbyshire encrinital marble and other beds of limestone, belong to that division of the animal kingdom called *radiaria*, from the different parts of which they are composed being arranged symmetrically around one common centre, as in the

asterias, or star-fish. As this animal is common on our shores, I shall offer a few remarks on its structure, to illustrate my subsequent observations. We have seen that the actinia (p. 542) is destitute of a skeleton, its tough skin and elastic gelatinous mass have no support. In the fungia, the polypus has an immoveable calcareous frame; while in the alcyonium, the rudiments of a skeleton are seen in the numerous separate spines, dispersed throughout the body; but the star-fish has an articulated or jointed frame-work to give stability to the soft parts. The body of the animal is covered by a tough integument, and each ray or arm is composed of a series of little bones, or *ossicula*, which are united together like the vertebræ of the spine, and form a flexible but powerful support. These bones are often found in a fossil state, and my museum contains some interesting examples of the skeletons of asteriæ, from the chalk. There are some kinds of star-fish which, instead of the five flat rays of the common species, have jointed arms, which surround the body and mouth, like the tentacula of the polype. These arms are composed of thousands of little bones, and the whole are inclosed in the common integument or skin. The asterias is a free animal; it floats at liberty in the water. Now, if we imagine a star-fish, like that which I have described, to possess a long flexible column, the base of which is attached to the rock, we shall have a correct idea of the general character of the *crinoidea*, or lily-shaped animals; which are so called from their fancied resemblance, when in a state of repose, to a closed lily. Of this family there are numerous genera in a fossil state, but only one living species is known.



TAB. 114.—ENCRINITES AND PENTACRINITES.

Fig. 1. Screw, or pulley-stone, a cast in the hollow of an encrinal column. 2, 4. Articulating surfaces of different kinds of encrinal vertebræ. 3, 5. Portions of encrinal stems, or entrochi. 6, 8, 10. Stems of pentacrinites. 7, 9. Separate bones of pentacrinites, or asteriæ.

40. ENCRINITES AND PENTACRINITES.—The name of *encrinite* is given to the species in which the bones of the column are circular or elliptical (upper row of figures of Tab. 114)—that of *pentacrinite* to those which have an angular or penta-

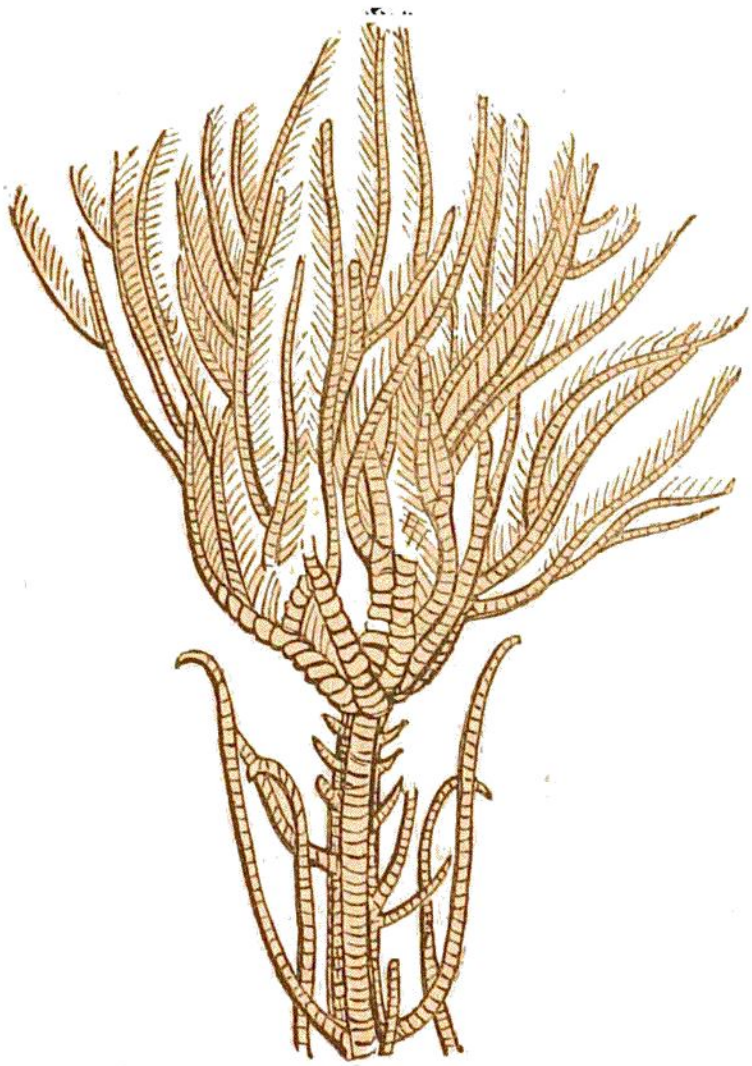
gonal stem (lower row of figures, Tab. 114). This extensive collection of the stems, and detached bones, exhibits the usual forms and variations observable in the structure of the ossicula belonging to different genera. It will be necessary to select only a few of the most characteristic for examination (Tab. 114). The bones when separated were called *trochites*,* and when several were united together *entrochi*, by the earlier collectors of fossils.† In some parts of England they are popularly known by the names of *fairy-stones*, and St. Cuthbert's beads; and the circular perforated kinds are occasionally found in the tumuli of the ancient Britons, having been worn as ornaments. The articulating surfaces, by which they were attached to each other, are variously and elegantly striated and grooved, presenting considerable diversity of ornament. The central perforation in some species is small and circular, in others polygonal (Tab. 114, figs. 2 to 10). The bones of the crinoidea, like the skeletons of mammalia, were of course formed by secretion effected by appropriate tissues; and, as in the fossil corals, the membrane may still be detected in their mineralized remains. Upon submitting encrinal vertebræ to the action of diluted muriatic acid, the calcareous earth is removed, and the animal tissue appears in transparent flocculi, bearing every mark of the crenated surface of the bones.‡

* Wheel-stones. † Org. Rem. vol. ii. p. 156.

‡ Parkinson. Org. Rem. vol. ii. p. 166.

41. STRUCTURE OF THE CRINOIDEA.—The skeleton of the crinoidea is formed of numerous ossicula or little bones, and consists of an upright articulated column, permanently attached by the base, and terminating at the summit in a cup-like receptacle, or basin, also composed of bony, jointed plates.

This basin, or pelvis, which contains the body of the animal, is formed of several plates, and surrounded by long, jointed arms, or tentacula; it is affixed to the stem by a pentagonal plate, which is placed in the centre of the base. The column, in most species, is of great length, and consists of separate bones, articulated, and regularly pierced in the centre, having the articulating surfaces, as I have already explained, ornamented with radiated, stellular, or floriform markings; it has numerous side-arms or lateral processes; and the inferior part has a pedicle, or process of attachment, by which the animal was fixed to other bodies. (See Tab. 117, 118.) In the recent state the skeleton was clothed with a fleshy, or coriaceous integument; the central perforation in the bones of the column was probably filled by a medullary, or nervous chord. The crinoidea, like the corals, were permanently attached to the spot where they grew. The mouth was placed in the centre of the upper part of the body, or pelvis, and the arms by expanding, like the tentacula of the polype, could seize their prey and bring it to the mouth. The only recent species known, belongs to the genus *pentacrinus* (Tab. 115), of which five or six specimens have been brought to Europe; it is a native of the West Indian seas.



TAB. 115.—THE BODY, AND UPPER PART OF THE STEM OF A PENTACRINUS.

(*From the West Indian Seas.*)

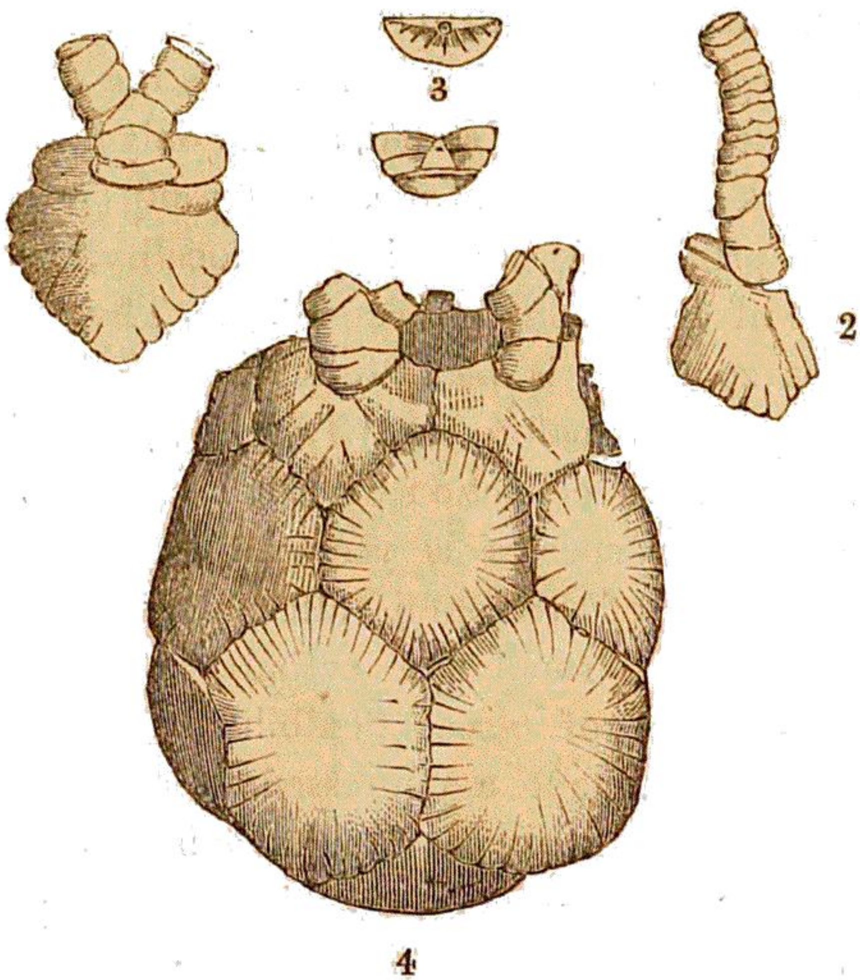
The number of bones in the skeleton is computed to exceed 30,000.

The detached ossicula of the crinoidea occur in myriads in the mountain limestone and Silurian rocks; and portions of the stems and separate bones of one species alone, form extensive beds of limestone in Derbyshire (page 587).

42. THE LILY ENCRINITE (Tab. 90.)*—One of the most elegant of the fossil crinoidea is the *lily encrinite,* which, as already stated, occurs only in the muschel-kalk of the new red sandstone group (page 472), 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 (Tab. 90), which was formerly in the collection of Mr. Parkinson. The stem of this species is remarkable, from being constructed of vertebræ 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 occupying the centre. It will elucidate the subject if we examine this specimen of a marsupite, in which the bases of two of the arms, or tentacula, are preserved (Tab. 116). A vertebral column attached to the central plate, at the base of the marsupite, would convert it into an encrinite; and in the large expanded plates of the pelvis, and the strong and simple phalanges of the arms, we have the elements of the more complicated and highly ornamented fabric of the lily encrinite.

* See page 473.

In another specimen, the plates which protected the upper cavity of the pelvis remain.* The marsupite



TAB. 116.—MARSUPITE FROM THE CHALK, NEAR ARUNDEL.

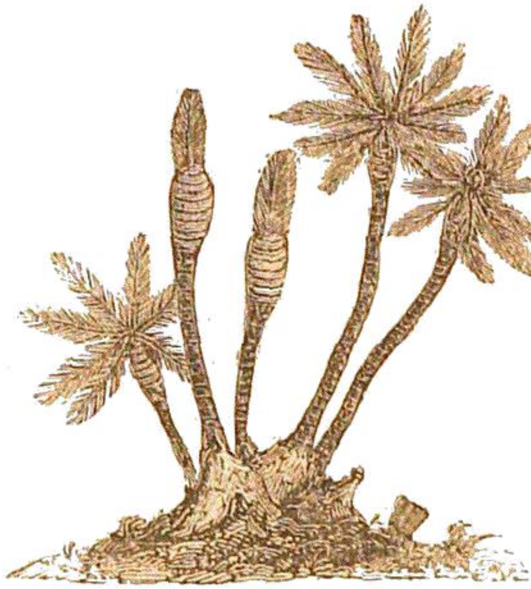
(*Drawn, and presented by G. A. Coombe, Esq.*)

Fig. 1. A plate with one of the arms or tentacula 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.

may be considered as a free encrinus—a link that unites the crinoidea with the star-fish; the form of

* Fossils of the South Downs, Plate XVI. fig. 6.

the perfect skeleton was shown in a previous lecture (Tab. 51, page 309).



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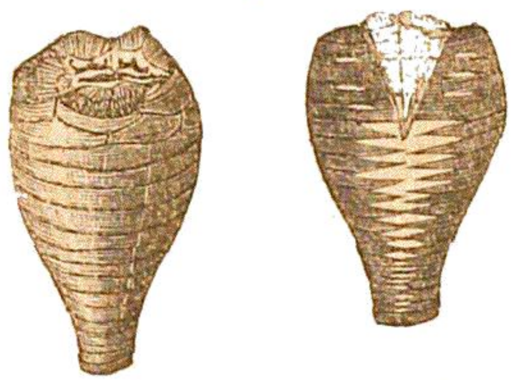

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TAB. 117.—PEAR ENCRINITE OF BRADFORD.

(*Apiocrinites rotundus of Miller.*)

Fig. 1. A group of apiocrinites restored, and represented as alive in the water; some with the tentacula expanded, others closed. 2. Body of the Bradford encrinite. 3. A vertical section of the same.

43. PEAR ENCRINITE OF BRADFORD; *Apiocrinites rotundus.* — Another form of crinoidea is

known by the name of the *Pear Encrinite* of Bradford, the oolitic limestone quarries in the vicinity of that town abounding in its remains. The body, or pelvis, of this species is of a pyriform shape, as its name implies; the stem is short, smooth, and strong; the arms are simple, and bear considerable resemblance to those of the marsupite. In this drawing, from Mr. Miller's valuable work on the Crinoidea, the animals are represented as if alive in the water (Tab. 118, fig. 1). This specimen (fig. 2) shows the state in which the body of the pear encrinite is usually found; and this vertical section (fig. 3) the form and disposition of the plates, or bones, of which it is composed. In the beautiful collection of Mr. Pierce, of Bradford, are specimens of the skeleton almost perfect from the base to the extremity of the tentacula. In the chalk a small species of this genus occurs, and detached ossicula are often met with, impacted in the flints.*

44. PENTACRINITES, ACTINOCRINITES, AND OTHER CRINOIDEA.—The pentacrinites differ considerably in their form and structure from the encrinites. The stems are furnished with numerous side arms, as may be seen in the column of the recent specimen (Tab. 115), and the arms sub-divide into innumerable branches. The lias shale of Lyme Regis abounds in *crinoideal* remains; and large slabs often have the whole surface covered with the

* Geology of the South-East of England, p. 111.

plumose tentacula of pentacrinites, converted into pyrites. Dr. Buckland has fully explained the structure of these animals, and given so many illustra-

TAB. 118.—CRINOIDEA FROM THE MOUNTAIN LIMESTONE, AND *SILURIAN FORMATIONS.*

Fig. 1. Cyathocrinitis pyriformis, from the Wenlock limestone. (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.

tions, that it is needless for me to pursue the inquiry.* I may, however, observe, that while the

* Bridgewater Essay, p. 411.

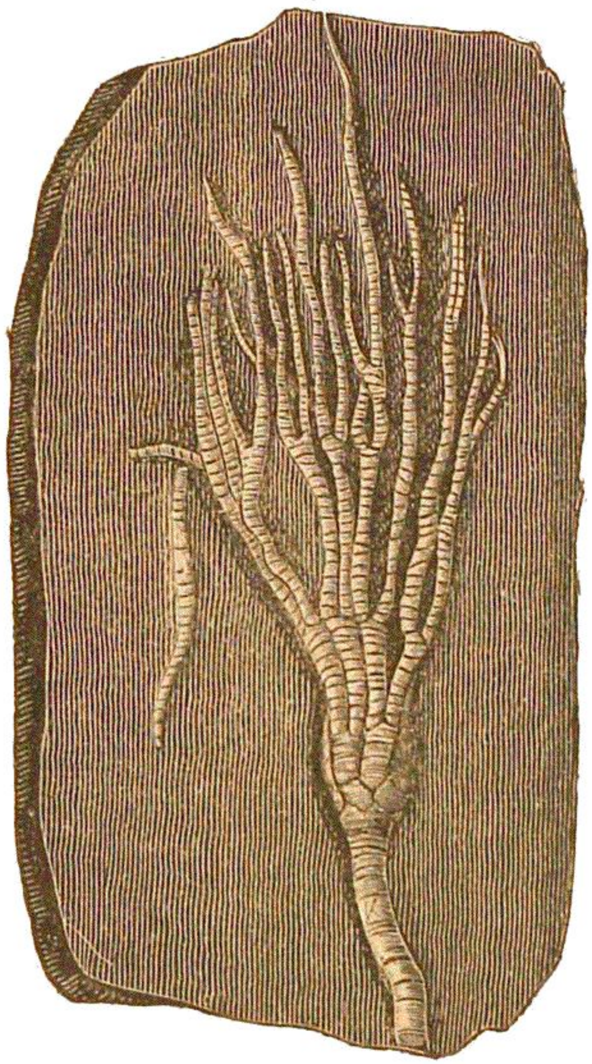
bones of a single encrinite may be numbered by tens of thousands, those of the pentacrinite amount to a hundred and fifty thousand; and as each bone must have had its appropriate muscles, the number of the latter, in a single pentacrinus, could not have been less than three hundred thousand.

Many other genera of this numerous family have been discovered, and are figured and described by Miller and other naturalists.* In some instances the body is closed up, 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 envelopement in its rocky sepulchre (Tab. 118, 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 (Tab. 119). 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 (Tab. 118, fig. 2). The pelvis or body of the actinocrinite is constructed of numerous bones, which in many species are richly ornamented; while in another genus, the *cyatho-*

* For a more particular account of the natural history of this extraordinary 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, 1821.

† *Actinocrinites*, signifying the radiated lily-shaped animal.

crinites,* the pelvis is very simple (Tab. 119), and composed of but few plates. The vertebral columns of these crinoidea are cylindrical.



TAB. 119.—CUP-LIKE ENCRINITE.

(*Cyathocrinites planus.*)

From the magnesian sandstone, Clevedon Bay, Somersetshire.

45. DERBYSHIRE ENCRINITAL MARBLE.—I have spoken of limestones formed of crinoideal remains. One of the most ornamental of the Derbyshire marbles is almost wholly composed of the stems

* Cup-like, lily-shaped animal.

and detached ossicula of a species of encrinite. (Tab. 120.) You are now so familiar with the process by

1

2

TAB. 120.—ENCRINITAL MARBLE OF DERBYSHIRE.

Fig. 1. Entrochi, or fragments of stems of encrinites, lying in relief on a block of limestone; from Sir George Sitwell, Bart. 2. Polished slab of Derbyshire encrinital marble; from J. Meynell, Esq.

which the durable remains of animals have been converted into stone, that it is not necessary to explain the mode by which this marble has been formed. In this specimen (Tab. 120, fig. 1) of the Derbyshire marble, which is so extensively manufactured into sideboards, tables, and ornaments, the encrinital remains are lying in relief: in the polished slabs (fig. 2) the sections of the inclosed stems and detached ossicula, constitute the peculiar and elegant markings of this limestone. In the chert which occurs in the Derbyshire strata, beautiful casts of the interior of the columns are met with, the calcareous matter of the original having been removed; in this state, the sharp impressions of encrinital stems form solid silicious cylinders, deeply marked with annular risings and depressions, and which are called pulley or screw-stones (Tab. 114, fig. 1).

46. Geological distribution of the crinoidea.—One recent species of pentacrinus is the only living representative of the once numerous family of the crinoidea. In the tertiary formations two species are known; these have been discovered in the London clay by N. T. Wetherell, Esq. of Highgate. The chalk contains the marsupite, the elliptical apiocrinite, and one or more species of pentacrinus. I have also a crinoideal column that is quadrangular. The oolite and lias are more prolific in the remains of this family, yielding about thirty species, belonging to nine genera. The saliferous system has fourteen species, including the

celebrated lily encrinite. The mountain limestone, and the Silurian and Cambrian formations, are the grand repositories of these remains; upwards of fifty species, belonging to twenty-five genera, have been obtained from those ancient deposits. The preponderance of these forms of existence in the ocean of those remote epochs, and their almost entire exclusion from the tertiary and modern seas, seem to indicate some remarkable change in the physical condition of the waters during these later periods, inimical to that great development of the crinoidea which existed in the oceans of the transition era.

47. CONCLUDING REMARKS.—From this review of the organization and economy of the polyparia, 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 polypi 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 determine the destinies of mighty nations; and that the materials of their dwellings, consolidated by chemical and mechanical agency, may become the foundations of islands and continents, and thus constitute new and favourable sites for the abode of the human race. 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 physical changes effected 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 system of nerves, 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 limestone, and ornament their temples and palaces with the marble, 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 conceptions of His wondrous works. Thus, in the eloquent language of Dr. Chalmers,—"while the telescope enables us to see a system in every star, the microscope unfolds to us a world in every atom. The one instructs us that this mighty globe, with the whole burthen of its people and its countries, is but a grain of sand in the vast field of immensity—the other, that every atom may harbour the tribes and families of a busy population. The one shows us the insignificance of the world we inhabit—the other redeems it from all its insignificance, for it tells us that in the leaves of every forest, in the flowers of every garden, in the waters of every rivulet, there are worlds teeming with life, and numberless as are the stars of the firmament. The one suggests to us, that above and beyond all that is visible to man, there may be regions of creation which sweep immeasurably along, and carry the impress of the Almighty's hand to the remotest scenes of the Universe—the other, that within and beneath all that minuteness which the aided eye of man has been able to explore, there may be a world of invisible beings; and that could we draw aside the mysterious curtain which shrouds it from our senses, we might behold a theatre of as many wonders as astronomy can unfold; a Universe within the compass of a point, so small as to elude all the powers of the microscope, but where the Almighty Ruler of all things finds room for the exercise of his attributes, where he can raise another mechanism of worlds, and fill and animate them all with the evidence of his glory."*

* This lecture was illustrated by an extensive collection of recent and fossil corals; and specimens of living actiniæ and zoophytes, from the neighbouring sea. Among the former were fine examples of caryophylliæ and meandrinæ, contributed by Mrs. Robertson; fungiæ, by Miss Crofts; madreporæ, dendrophylliæ, and astreæ, by Lady Mantell; agariciæ, by Miss Ellen Gladwin; gorgoniæ and milleporæ, by Miss E. Mahony, and William Tennant, Esq.; flustra foliacea, by Robert Hannay, Esq.; and sarcinulæ, turbinoliæ, and milleporæ, by Rev. T. Trocke.

LECTURE VII.

1. Introductory remarks. 2. The carboniferous system. 3. The coal measures. 4. Coal-field of Derbyshire. 5. Coalbrook dale. 6. Coal-shales, and vegetable remains. 7. Carboniferous, or mountain lime-stone. 8. Derbyshire lead mines. 9. Carboniferous system of Devonshire. 10. The Devonian system, or old red sandstone. 11. Geographical distribution of the carboniferous system. 12. Volcanic rocks of the carboniferous system. 13. Trap-dikes of the carboniferous system. 14. Organic remains of the carboniferous system. 15. Organization of vegetables. 16. Coniferous trees. 17. Climate and seasons, indicated by fossil wood. 18. Vertical trees in carboniferous strata. 19. Trunks of coniferæ in Craigleith quarry. 20. Microscopic examination of fossil trees. 21. Nature of coal. 22. Mineral oil, naphtha, and petroleum. 23. Bitumen, amber, and mellite. 24. The diamond. 25. Anthracite, cannel coal, and plumbago, or graphite. 26. Nature of petrifaction. 27. Artificial petrifactions. 28. Different states of the fossilization of wood. 29. Hazel-nuts filled with spar. 30. Silicification, or petrifaction by silex. 31. Plants in agates, &c. 32. Plants of the coal formation. 33. Fossil mare's-tail, or equisetum. 34. Fossil ferns. 35. Sigillariæ, or fossil arborescent ferns. 36. Lepidodendron. 37. Fossil club-moss, or lycopodites. 38. Stigmaria. 39. Seed-vessels in coal. 40. Coniferæ. 41. Review of the carboniferous flora. 42. Formation of new coal-measures. 43. Corals and crinoidea of the carboniferous system. 44. Shells of the carboniferous system. 45. Crustacea. 46. The limulus, or king-crab. 47. Trilobites. 48. The eyes of the trilobite. 49. Insects of the coal formation. 50. Fishes of the carboniferous and Devonian systems. 51. Retrospect—the flora of the ancient world.

1. Introductory remarks.—The examination of the recent and fossil zoophytes, which formed the subject of the last discourse, will enable us to comprehend many of the phenomena relating to the

ancient coralline rocks hereafter to be noticed. I now resume the geological argument from which we have for a while digressed, and hasten to the consideration of the carboniferous system, which in the stratigraphical arrangement (page 194, Pl. VII.) succeeds the saliferous deposits described in the fifth lecture.

The strata comprised in the carboniferous system, so named from its being the great depositary of that important substance called coal, consist of sandstones more or less felspathic, of dark bituminous shales, and coal; and of grey limestones: they admit of three natural divisions. The uppermost is composed of a vast number of alternations of coal, shale, ironstone, and sandstone; the middle, of chert, sandstone, quartzose conglomerates, and limestone, with immense quantities of shells, polyparia, crinoidea, and other marine exuviæ; and the lowermost, of sandstones and conglomerates, generally of a dull red colour, and resembling, in their lithological characters, those of the new or upper red sandstone. I propose to describe—firstly, the general characters of the strata, and their geographical distribution; secondly, the nature of the coal and of the fossil plants, which are scattered through the carboniferous rocks; thirdly, the animal remains; and lastly, review the flora of the ancient world.

2. THE CARBONIFEROUS SYSTEM.—The followi g tabular arrangement will convey a general idea

of the characters and relations of this group of deposits.

1. The coal measures.

(*The uppermost in the series.*)

Sandstone, shale, and numerous beds of coal; with layers of ironstone irregularly stratified, abounding in terrestrial plants.
Beds of limestone, with fresh-water shells.
Total thickness, 1000 yards.

2. The carboniferous, or mountain limestone.

Millstone grit, sandstone, shale, and coal, with plants.
Limestone and flagstone, abounding in crinoidea, with plants.
Lower, or scar-limestone, with zoophytes in profusion, crinoidea, productæ, spiriferæ, orthoceratites, ammonites, goniatites, bellerophon, trilobites, &c.
Total thickness, about 800 yards.

3. Old red sandstone, or marl.

(Devonian system, *of Professor Sedgwick and Mr. Murchison.**)

Quartzose conglomerates, and silicious sandstones, without organic remains.
Flagstones, marls, and concretionary limestones, provincially termed *cornstone;* laminated reddish and green micaceous sandstones, called *tilestones*. Fishes, orthoceratites, nautili, and several genera of mollusca occur, but organic remains are comparatively rare.
Total thickness estimated at 3500 yards.

Such is a synoptical view of the strata usually comprehended in this series; but the recent obser-

* Annals of Philosophy, No. 89, p. 259.

vations of Professor Sedgwick and Mr. Murchison, have shown the propriety of separating the *old red sandstone* from the carboniferous system, and of classing it as a distinct formation, characterised by peculiar organic remains. Thus we have the new red, or saliferous formation, passing into the carboniferous, and the latter into the old red sandstone, or *Devonian*, as it is now proposed to designate this group of strata, for reasons subsequently to be noticed.

3. THE COAL MEASURES.—The bituminous substance termed coal is simply vegetable matter altered by a chemical process, which will hereafter be explained. It occurs in strata which vary from a few inches to a fathom in thickness, having interposed beds of shale, clay, micaceous sandstone, and ironstone in layers and nodules. Groups of alternations of this kind occupying circumscribed areas, are termed basins. Mr. Bakewell observes that the strata thus disposed may be explained by a series of muscle-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.

The usual characters of a coal-field, as a series of strata of this kind is termed, are shown in the section of the South Gloucestershire coal basin (Pl. IX. fig. iv.).* Here we perceive that the old red sandstone, the lowermost group, has been elevated into a position almost vertical, and a layer of mountain limestone lies immediately upon it, and partakes of the same inclination. This is succeeded by a conformable bed of millstone-grit, which is followed by alternations of coal and grit. The unconformable position of the lias and inferior oolite is here shown (see page 462). The mountain limestone and millstone grit are seen on the opposite flank (*on the left*) of the elevated ridge of old red sandstone. It will be instructive to enumerate the deposits exhibited in this section, in their chronological order; that is, in their relative position if they were piled upon each other, and had suffered no displacement: commencing with the lowermost or most ancient.

Pl. IX. fig. iv.—Old red sandstone of the Mendip Hills.

1. Mountain limestone.
2. Millstone grit.

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.

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* England and Wales, p. 428.

In another line of section in the same district, we find a similar general arrangement.

1. Old red sandstone. Pl. IX. fig. ii. *left hand section.*
2. Carboniferous limestone.
3. New red sandstone.
4. Lias.
5. Inferior oolite.

The term basin, applied to these accumulations of coal, must be taken only in a general sense; for although some carboniferous deposits may have been formed in circumscribed depressions, it is evident that 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, so admirably illustrated by my friend Mr. Bakewell,* will serve as a type of the English series; the geographical distribution of the principal coal-measures in England is shown in the map. (Pl. X.)

The strata of 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 carboniferous limestone is placed a bed of calcareous slate or

* Introduction to Geology, p. 149.

shale, varying in thickness from three to six hundred feet. The compact strata of this bed are separated by softer 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; hence the geological name, *mill-stone grit*, by which it is distinguished. Above the grit are the regular coal strata, comprising sandstones of various qualities and often in exceedingly thin laminæ; indurated clay; ironstones, the nodules of which contain organic remains; and softer argillaceous beds, which being of a slaty structure, are called *shale*. Two of these layers of clay abound in fresh-water muscle-shells, of extinct species, and are termed *muscle-bind;* these bivalves very much resemble the *uniones* of the wealden (page 377). 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 beds of limestone shale 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 both in the succession and thickness of each. Interruptions to the continuity of the strata, from cracks or fissures which have taken place since their original deposition, are very frequent. In this diagram (Pl. VII. 7), a fault of this kind (see page 192) is represented as having displaced three beds of coal. This is an example of a simple fissure and dislocation; but dikes, or intrusions of other mineral matter, also occur, separating the beds as it were by vertical walls, which are from a few inches to many yards in thickness. The dikes are sometimes composed of indurated clay, but more frequently of the ancient volcanic rock, called trap, or basalt. This diagram (Pl. VII. 15) represents a trap dike intruding through the carboniferous and other systems, and spreading over the chalk. The effect of these lava currents on the rocks they transverse, will be considered in the next lecture. The mottled rock in Derbyshire, called *toadstone*, is clearly a pyrogenous mass, that has been erupted in a melted state.

5. COALBROOK DALE.—In Shropshire, the carboniferous strata are disposed in several detached areas or coal-fields.* Around Shrewsbury the coal-beds are associated with "a limestone, of fresh-water or estuary origin, peculiar to the coal-fields of the central counties of England,"† and containing

* Silurian System, p. 83.

† Consult Mr. Murchison's admirable description of the Carboniferous System; Silurian System, chap. vi.

fresh-water crustacea (*cypris*, see p. 380), shells (*cyclas*, *planorbis*, and *unio*, p. 350), and fishes. But the most important and productive carboniferous tract in Shropshire is *Coalbrook dale*, which is situated on the east side of the range of rocks forming the Wrekin and Wenlock Edge, the coal strata being superposed on carboniferous limestone. Beds of ironstone occur, abounding in nodules, with organic remains, of which I shall speak hereafter. This coal-field is remarkable for the dislocated and shattered state of the strata, and the intrusion of volcanic rocks, which do not appear as dikes, or in the fissures of the beds, but rise up in mounds or protuberances. The walls of the fissures are in some instances several yards apart, the intervals being filled with debris. Beds 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, into which flowed a considerable river, subject to occasional freshes; the frequent alternations of coarse sandstone and conglomerates, with beds of clay or shale containing the remains of the plants brought down by the river, support this opinion.* The series of strata forming this carboniferous accumulation, consists of quartzose sandstone, indurated clay, slate-clay, and coal. A pit sunk in Madely colliery,

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

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 crustacea are abundant in the shale and ironstone nodules; and the remains of insects sometimes occur.

This brief notice of two remarkable coal-fields will suffice to convey a general idea of the nature of carboniferous deposits. To exemplify those of the United Kingdom alone would require a course of lectures. The admirable memoirs on the British coal-fields in the Geological Transactions, by some of our most eminent observers, and in the works of Bakewell, Conybeare, Phillips, Lyell, De la Beche, Dr. Buckland, Murchison, and others, will afford those who wish to pursue the inquiry, information of the most important and interesting nature.

6. COAL-SHALES, AND VEGETABLE REMAINS.— The shales, or layers of slaty-coal, are the great depositories of the fossil vegetables. These strata intervene between the beds of bituminous coal, and when the latter are extracted, the roof and floor of the mines or galleries are composed of the schistose beds, which are not made use of for economical purposes. In these large slabs of shale, from

Newcastle, for which I am indebted to William Hutton, Esq., vegetable remains occur between every lamina, and as I flake off portions bearing the leaves of ferns and other plants, another series is disclosed; the whole mass being formed of leaves and stems, closely pressed together in clay. The carbonaceous matter is sometimes in an unconsolidated state, exhibiting the matted fibres, leaves, and stems of the plants. This structure, 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 beds.* 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 by Dr. Buckland to be the most interesting of any he had 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 most graceful foliage,

* Silurian System, p. 100.

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." *

7. CARBONIFEROUS, OR MOUNTAIN LIMESTONE.—The strata comprised in this geological group, consist of — 1st, Millstone-grit: — 2, Bluish-grey limestone traversed by veins of calcareous spar, abounding in encrinital remains and other marine exuviæ; in some localities it is rich in lead ore, and hence has been called metalliferous limestone:—3, Chert, sandstone, shale, and coal of inferior quality.

* Bridgewater Essay, p. 458.

The *millstone-grit* is a silicious conglomerate composed of the detritus of primary rocks; it contains rolled fragments of granite of various magnitudes, from the size of a pea to that of a large pebble, which are cemented together by a crystalline quartzose paste. Sandstones are associated with the grit, both having one common origin: the materials of which they are composed are clearly the detritus of granitic rocks, produced by the action of water. Fragments of shale, coal, red sandstone, stems of plants, &c. are occasionally found imbedded in the grit. The millstone grit, however, is but of limited extent, and in some localities is altogether wanting, or is superseded by chert, or sandy limestone.

The *carboniferous* or *mountain limestone* is of a sub-crystalline texture, and many varieties are sufficiently compact to bear a fine polish, their surfaces presenting sections of inclosed crinoidea, corals and shells. The prevailing hue is a light bluish-grey, the organic remains being of a pure white; but some varieties have a ground of pale red, while others are nearly black, the imbedded shells having a deep ochreous colour. The Derbyshire marbles, and those of St. Vincent's rock, at Clifton, are familiar examples of the finer varieties of the mountain limestone. It is largely developed over the central and northern parts of England, and the south-west of Scotland; and is the predominating rock throughout a great part of

Ireland. In Somersetshire, Gloucestershire, Shropshire, North and South Wales, and Derbyshire, this limestone constitutes as it were an entire calcareous mass, which is interposed between the old red sandstone, or where that is wanting, between the more ancient silurian and slate rocks below, 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 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 giving rise to 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 encrinital or Derbyshire marble (page 588) has already been described; marbles with shells and corals also occur, and are employed for ornamental purposes. In some parts of this district, and in the Mendip hills, layers and nodules of the silicious substance called *chert*, are imbedded in the calcareous rock, like the flints in chalk. The masses of chert before us, collected by Sir George Sitwell, Bart., are fine examples of the curious fossils called screw-stones, described in the last lecture (page 577). The chert or silex has flowed into the interior of the stems of the encrinites, and the cavities of the shells, and become consolidated; the calcareous part of the organic bodies has since decomposed, leaving the chert, which exhibits sharp casts of the interior, and impressions of the external surface. So abundant are organic remains in some beds of the mountain limestone, that it is computed corals, shells, and crinoidea, constitute at least three-fourths of the mass.

8. 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 rock, and extend in some instances into the *toad-stone*, the ancient volcanic bed already mentioned. 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 spar. 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, as you perceive in the specimens before us, is of a bluish-grey colour, and sometimes

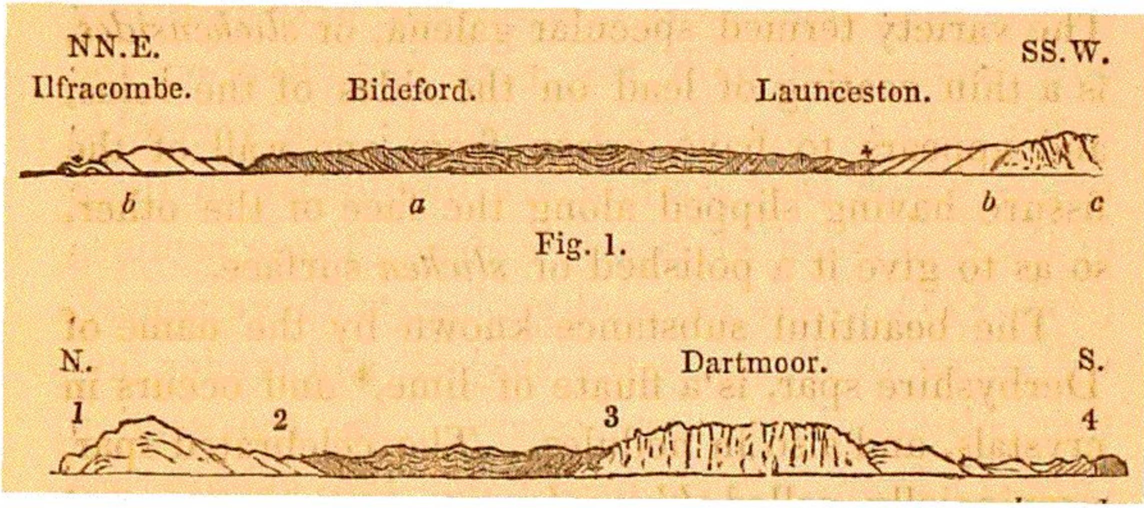
occurs in cubic and octahedral crystals; it is also found disposed in thin layers, as well as in veins. It is accompanied by fluor and calcareous spar, sulphate and carbonate of barytes, iron pyrites, &c. The variety termed specular galena, or *slickensides*, is a thin coating of lead on the sides of 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 substance 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.

9. CARBONIFEROUS SYSTEM OF DEVONSHIRE.—The labours of Messrs. Sedgwick and Murchison have shown that an extensive series of rocks in Devonshire, termed *culmiferous*, from their abounding in *culm*, or slaty coal, and referred by Mr. De la Beche and others to the transition or greywacké formations, belongs to the carboniferous systems, and in fact constitutes a trough of coal-bearing strata lying on the old red sandstone, but much altered in character and position by intrusions of granite and other igneous rocks. By a careful examination of the organic remains, the culmi-

* Lime in combination with fluoric acid.

ferous beds are found to be connected with the new red sandstone above, and the old red sandstone below; the latter being characterised by its peculiar fossils, and passing into the Silurian system.



1. North Foreland. 2. Barnstaple. 3. Oakhampton. 4. Start Point.

TAB. 121.—SECTION OF THE STRATA OF DEVONSHIRE.

(*Professor Sedgwick and Mr. 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 old red system (*b*, *b*); a protrusion of granite (*c*) occurring on the SS.W.

Fig. 2.—Section from north to south; the carboniferous beds (*a*) repose on the old red strata in the north (*b*); while on the south the granite of Dartmoor has been protruded (*c*); the old red system (*b*) re-appearing in the southern part of the county, terminated by a band of micaceous schists. *a*, Carboniferous system; the culmiferous rocks of Devonshire. *b*, Old red or Devonian system, consisting of slaty rocks, sandstone, and limestone. *c*, Granite. *d*, Micaceous schists; altered or metamorphosed strata.

To avoid the ambiguity and confusion arising from the continuance of the old terms, it is proposed to designate the group of strata hitherto called the old red sandstone, or marl, the "DEVONIAN SYSTEM," which includes many of the older stratified rocks of Devonshire and Cornwall. Thus the most ancient fossiliferous strata will constitute three great systems, which pass into each other, namely, the Carboniferous, Devonian, and Silurian. 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 (Tab. 121), by the eminent geologists above named, will serve to illustrate the subject, and render further observations 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 old red or *Devonian* system. The section (Fig. 2), from north to south, shows the carboniferous strata (*a*), flanked on the north side only by the old red slaty rocks (*b*), the granite of Dartmoor (*c*) having been protruded on the southern edge; "while the old red system re-appears in the southern part of the county, terminated by a band of micaceo-chloritic schists, which are perfectly parallel to the great disturbing axis of Cornwall and Devon, and are probably altered or metamorphosed strata." *

10. THE OLD RED SANDSTONE, OR DEVONIAN

* Classification of the older stratified rocks of Devonshire and Cornwall, by the Rev. Professor Sedgwick and R. I. Murchison, Esq. Annals of Philosophy, No. 89. April, 1839.

SYSTEM.—The *Old red sandstone*, or marl, lies beneath the mountain limestone, and is largely developed in Devonshire, Herefordshire, Monmouthshire, and in the south-east border of the Grampians. It consists of many varieties and alternations of conglomerates, shales, and sandstones. The sandstones are in various states of induration, and when schistose, are employed for roofing. The conglomerates contain abundance of quartz pebbles. The red colour predominates in the cementing material and in the marls, and is derived, like that of the new red, from the peroxide of iron. The formation of this group of strata has manifestly resulted from the waste and degradation of the ancient slate rocks, of which I shall hereafter speak; the detritus being cemented together, more or less compactly, by red sand or marl, into coarse conglomerates. The slate rocks of Cambria, elevated by convulsive movements, were subjected to degradation, and thus accumulations of pebbles, sand, and mud, were formed in hollows or depressions of the sea. The mountains of Scotland are bordered by enormous depositions of a like character; and those of North and South Wales by extensive beds of red pebbly sandstone.* It would appear from the observations of some eminent geologists, that prior to the formation of the old red sandstone, the Cambrian slaty group of sands, rocks, flags, &c. with porphyritic conglomerates, had been long consolidated; and

* Phillips.

that subterraneous movements elevated them, threw the strata on edge, and formed an irregular island: at the same time, the Grampians, Lammermuirs, and the slaty tracts of Ireland and Wales, and the Ocrynian chains of Cornwall, stood above the waters.

As a whole this system contains, comparatively, few organic remains, but locally peculiar fossils abound. These, which are figured and described by Mr. Murchison,* consist of several species of spiriferæ (see Tab. 91), productæ, cucullæa, bellerophon, ammonite, orthoceras, turritella, &c. The scales and other remains of several species of fish occur; one remarkable genus, the *cephalaspis* (Tab. 136), is very characteristic of the system. The scales and fragments of these fishes are generally of a bluish and purple plum colour, which, contrasting strongly with the dull red tint of the surrounding rock, renders the smallest portion of these ichthyolites easily recognisable.† Fuci are, I believe, the only known vegetable remains.

11. GEOGRAPHICAL DISTRIBUTION OF THE CARBONIFEROUS SYSTEM.—I have briefly alluded to the distribution of the carboniferous system of England,‡ and further details would be irrelevant

* Silurian System, vol. ii. Plates 1, 2, 3.

† Mr. Murchison, p. 588.

‡ The principal coal basins in England are those of Somersetshire, Gloucestershire, North and South Wales, Dudley, Shropshire, Leicestershire, Lancashire, Nottingham, Derby-

in these lectures. I cannot, however, omit to notice one most interesting locality, from which many of the specimens before us were collected.

The magnificent gorge of the Avon at Clifton, so well known by the name of St. Vincent's Rocks, is flanked by an uninterrupted succession of mural precipices, and presents an unrivalled natural section of the carboniferous limestone. The calcareous beds rest conformably on strata of the Devonian, or old red sandstone system, which may be seen on both sides the river, near Cook's Folly, extending on the south under Leigh-down and Weston-down. On the north the old red sandstone passes towards Westbury.*

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 reminds the English traveller of the banks of the Derwent or the Wye.†

shire, Yorkshire, Cumberland, Durham, Newcastle; of the Forth and Clyde; and the central districts of Ireland.—See *Phillips's Guide to Geology.*

* Conybeare. † Phillips.

The coal of central France reposes on granite and other primary rocks, without the intervention of limestones or sandstones.* In Poland, the lower beds of the coal measures pass insensibly into the transition rocks upon which they rest. In North America, the carboniferous series is largely developed, and has been ably illustrated by Professors Silliman, Eaton, Hitchcock, and other American geologists. The *coal* of the United States appears, however, to be referable to different geological eras; the most ancient belonging to the transition series, the next to the European carboniferous system, and the third to the brown coal, or tertiary lignite. The coal, culm, or *anthracite*, of Pennsylvania, (of which, through the kindness of Professor Silliman and Dr. Morton, I have a fine series, with vegetable remains), is associated with conglomerates, sandstones, and argillaceous slate; and the conglomerates are composed of quartz pebbles, like those of our old red sandstone. In the valley of the Connecticut, bituminous coal is stated by Professor Hitchcock to be intercalated in a group of strata, which he refers to the new red sandstone.† Deposits of anthracite, or stone coal, 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. The base of the whole extent of the plain of that mighty

* De la Beche. † Geology of Massachusetts.

river appears to be carboniferous limestone; it has been perforated to a depth of six hundred feet, and contains trilobites, orthoceratites, and other remains, which are characteristic of this formation. The limestone extends under the Alleghany mountains in 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. This coal-field is 1500 miles in length, and 600 in breadth. Ironstone abounds in these deposits, and mines of lead occur over a district of two hundred square miles, between the Missouri and the Illinois.* Thus the coal basin of the Mississippi appears to possess all the essential features of the English carboniferous series.

Coal is found in Asia; and has long been worked in China. In Van Dieman's Land, carboniferous strata occur, associated with sandstone, and yield coal abundantly.†

12. Volcanic rocks of the carboniferous epoch.—I have alluded to the intrusions of volcanic matter, which are found in the carboniferous strata, and will now offer a few remarks on the phenomena which these pyrogenous rocks exhibit. One of the most remarkable and well known volcanic substances of this era in Derbyshire, is the rock called *toadstone*, so named from its being

* Stuart's Travels in the United States.

† Conybeare and Phillips.

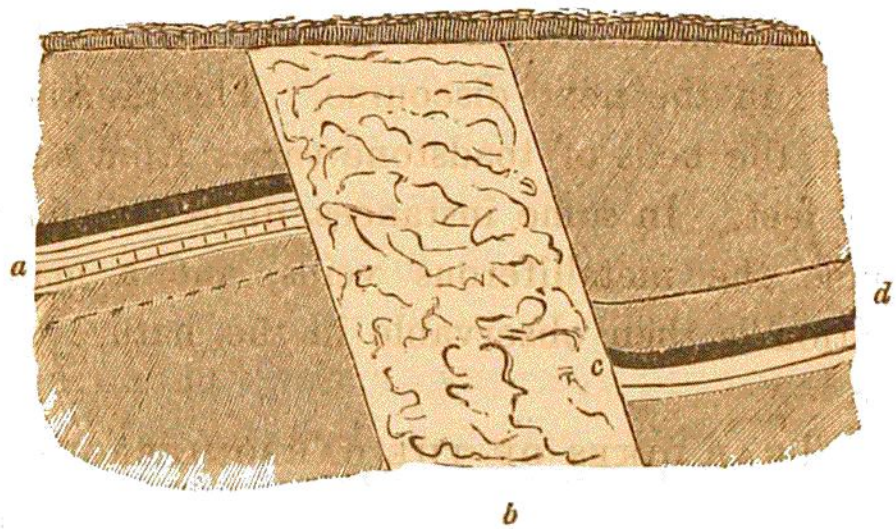
mottled with green and yellow. Three distinct beds of this ancient lava are interpolated in the mountain limestone of that district.* The toadstone is a compact mass, consisting of small nodules of white and yellow calcareous spar and green earth, imbedded in a dark greenish paste of basalt. Sometimes the nodules are decomposed, and the stone is then vesicular or cellular, resembling porous lava. This rock, in some instances, passes into common basalt, an ancient volcanic product, which I shall describe in the next discourse. The thickness of each of the beds of toadstone 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.

13. TRAP DIKES OF THE CARBONIFEROUS SYSTEM.—Trap dikes, which are intrusions of a hard, dark green, fine grained, volcanic stone, in fissures which intersect the stratified deposits, are common in the carboniferous system; and in Yorkshire there is one of prodigious extent and thickness, named the *whin sill*, which traverses the coal-measures, red sandstone, and lias, and passes from High Teesdale to the confines of the eastern coast, a distance of upwards of sixty miles.† The *faults*,

* Consult Mr. Bakewell's Geology; and Conybeare and Phillips's Geology of England and Wales.

† Professor Sedgwick. Mr. Bakewell's observations on the phenomena of trap dikes are highly interesting and philosophical.

or separations and dislocations of the coal beds arising from intrusions of trap and other erupted rocks, are very numerous, and in some instances present phenomena of considerable interest. The subject is fully illustrated by Mr. Murchison, in his late publication;* it will suffice for our present purpose to select one example. This sketch (Tab. 121[bis]), from Mr. Murchison's work, represents a



TAB. 122[bis].—SECTION OF A FAULT IN THE COAL-FIELD OF DUDLEY, NEAR BARROW HILL.

(T. I. Murchison, Esq.)

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.

fault in the coal-field of Dudley, near Barrow hill. The coal-beds are rent asunder to an extent of 140 yards; and the erupted mass (*b*) has upcast the strata on the south-east 90 yards (*a*); the sides of the fissure being inclined from 80° to 90°. You

* Silurian System, p. 504.

will of course understand that the beds of coal (*a* and *d*) were once continuous, and in a horizontal direction; the effect of the intruded trap has been to twist upwards the edges of the lower bed of coal (as is shown at *c*). These carboniferous beds rest on red conglomerate.

The alterations produced in the strata in contact with these ancient lava currents will be considered in the next lecture; at present it is only necessary to state, that changes of the most striking character occur in the coal and its associated beds, wherever they lie within the range of the volcanic influence; the coal being charred, and deprived of its bituminous quality, and oftentimes changed into culm or anthracite.

14. ORGANIC REMAINS OF THE CARBONIFEROUS SYSTEM.—The animals and plants entombed in the carboniferous group are exceedingly numerous, and well-defined. In the coal, the vast abundance of terrestrial plants, the presence of fresh-water shells with but few marine species, together with the entire absence of zoophytes, crinoidea, and other marine exuviæ, which abound in the mountain limestone, present a remarkable contrast with the calcareous deposits of this system. The shales of the limestone, however, contain vegetable remains. Marine fishes, shells, corals, and crinoidea, swarm in the limestone, but are of rare occurrence in the old red sandstone.

It is a circumstance worthy of remark, that the coal beds of the south of England do not contain marine remains, whereas in the north, certain beds abound in ammonites, and other inhabitants of the sea. At Burdie House, near Edinburgh, beds of limestone, with fresh-water shells, crustacea, sauroid fishes, and terrestrial plants, have been discovered in the carboniferous series by Dr. Hibbert; they appear to be an intercalation between the marine deposits of the same group,* like those of Coalbrook dale, and were probably formed in an estuary communicating with a river of considerable extent.

In the immense accumulations of the early vegetation, of which the coal-measures are composed, we have presented to us, in the most legible and striking characters, the peculiar flora of the remote epoch in which those deposits were produced. But 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 the mere external characters are, for the most part, either 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 (page 127) to reconstruct those extinct forms of being; in like manner we must now call to our aid that branch of

* On the fresh-water limestone of Burdie House, near Edinburgh, by Samuel Hibbert, M.D. F.R.S. Edinburgh. Philosophical Transactions, vol. xiii.

science which treats of vegetable organization, and we shall thus be enabled to restore anew the forests of extinct palms and tree-ferns, the groves of liliaceæ, and all the luxuriant tropical vegetation which flourished in the carboniferous epoch of our globe. I must, however, restrict myself to a brief enunciation of a few leading botanical principles. The works of M. Adolphe Brongniart,* and of Dr. Lindley and Mr. Hutton,† should be consulted by those who would pursue this most attractive department of natural history.‡

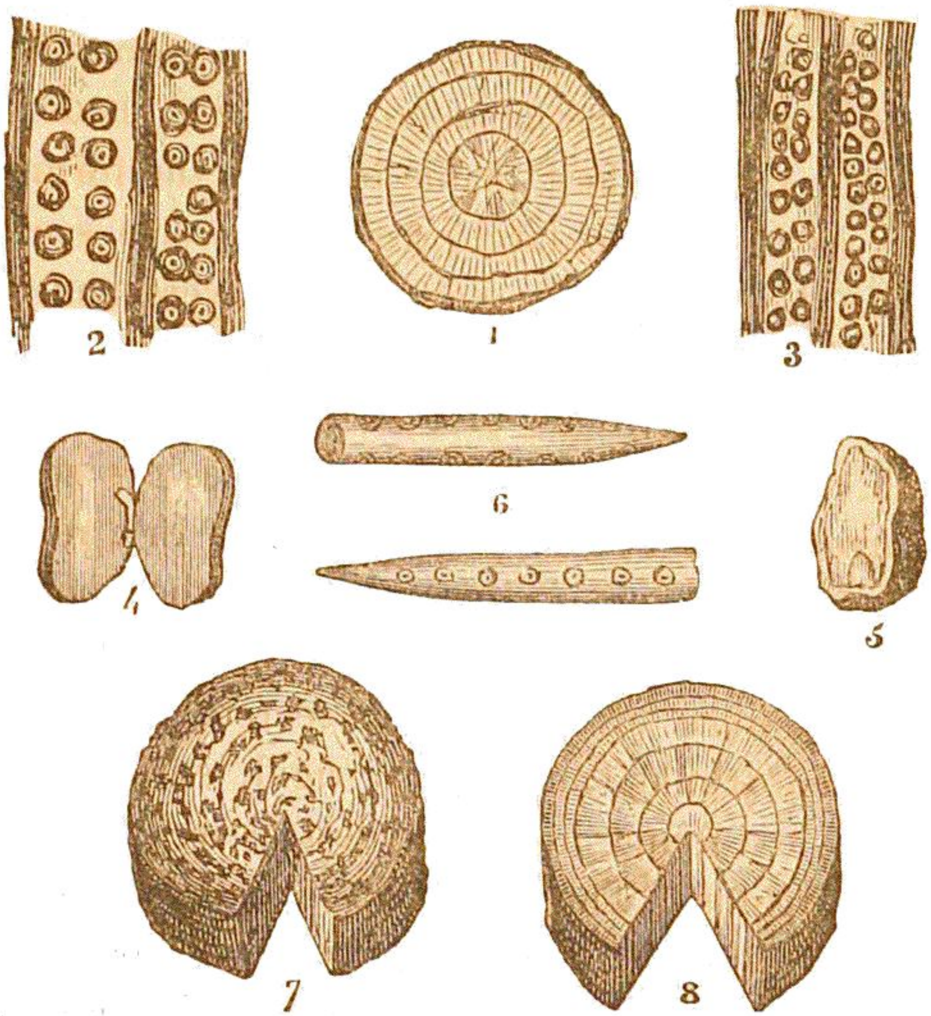
15. ORGANIZATION OF VEGETABLES.—In the previous discourse, the complex organization of even the most minute forms of animal existence was remarked; the structure of vegetables, on the contrary, presents a remarkable simplicity. While in animals every separate function is effected by an organ of peculiar 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 consists of a solid spongeous texture, made up of cells or vessels, containing fluids, or other matter. This organization is differently

* Histoire des Végétaux 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.

arranged in the grand classes of the vegetable kingdom. In the most 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. These plants have no flowers, and hence are named *cryptogamic*. 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* (Tab. 122, fig. 5), as the onion, lily, &c.; and also called *endogenæ* (*from within*), because increase takes place from the innermost part of the stem; and the *dicotyledonous*, from the seeds having two lobes (Tab. 122, fig. 4), as the bean, almond, &c.; these are also termed *exogenous* (*from without*), the new matter being added externally to the old layers, and thus forming annual circles of increase, as in the oak, elm, &c. (Tab. 122, fig. 8). The section of the monocotyledonous stems (as the cane, palm, &c.) present therefore, openings of tubes, which are condensed towards the outer surface (Tab. 122, fig. 7), while the dicotyledonous exhibit annular lines of growth with diverging rays, and a central pith (Tab. 122, fig. 8); the latter character is of peculiar import-



TAB. 122.—ILLUSTRATIONS OF VEGETABLE STRUCTURE.

Fig. 1. Section of a coniferous tree, showing the concentric and radiated structure. 2. Longitudinal section of a pine tree, magnified to exhibit the spotted vessels. 3. Longitudinal section of the vessels of an araucaria, magnified to show the glands or ducts arranged alternately. 4. A dicotyledonous seed split open; the germ is in the middle. 5. Section of a monocotyledonous seed, with the germ below. 6. Dotted tubes, or cells of coniferæ. 7. Section of a monocotyledonous stem. 8. Section of a dicotyledonous tree, showing concentric circles, medullary rays, and the central pith.

ance, because all other classes are destitute of a central cellular column.

16. CONIFEROUS TREES.—In some groups of dicotyledonous trees the elongated cells, or tubes, are studded with spots or glands (Tab. 122, fig. 6), and this is particularly the case in the woody fibres of the *coniferæ;* the name (*cone-bearing*) is derived from the fruit of these plants being in the form of a cone, as in the fir, larch, &c.; transverse sections of the stems show the concentric layers and radiated structure peculiar to the dicotyledonous class. In this magnified view of a slice of the common fir (Tab. 122, fig. 2), the spots or glands are seen to be arranged in double parallel lines. In a remarkable family of pines, the *auracaria,* the spots are 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 *auracaria* (or, *altingia excelsa,*) 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 species of pine, which attains a height of two hundred feet, and a circumference of thirty: it will not thrive in the open air in this country.

The limits assigned to these lectures will not allow me to dwell at length on any other of the numerous co-relations of structure presented in vegetable organization. I may, however, observe, that even in the foliage of the different orders, there are such evident distinctive characters, that the botanist, from a mere fragment of a leaf, could 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 of the lily.* The application of these principles to the investigation of the fossil remains of vegetables we may now consider.

17. CLIMATE AND SEASONS INDICATED BY FOSSIL WOOD.—In the course of these lectures, it has been repeatedly 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 can 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 so forcibly exemplified the inductive process by which such results may be obtained, that I shall here avail myself of his interesting remarks.

* See Fossil Flora of Great Britain, vol. i. p. 27. The general reader will find the organization of vegetables explained in a clear and pleasing manner, in a little volume entitled, "POPULAR BOTANY," by James Main, Esq. A.L.S. London, 1835.

"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. If we were to select a number of trees of about the same size, we should probably 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."

18. VERTICAL TREES IN CARBONIFEROUS STRATA.—The occurrence of the trunks of fossil trees in a vertical position, has already been noticed; the petrified forest of Portland, with its beds of vegetable mould, having early drawn our attention to this phenomenon (page 361). Stems of plants, standing erect in the strata, occur in many coal mines; and an interesting example is described by my friend M. Alexandre Brongniart, a distinguished French philosopher, as occurring at Tréuile, near St. Etienne, in the department of the Loire. This mine is most favourable for observation, for it is, in truth, a quarry in the open air, and exposes a natural section of the strata, which consist 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 is composed of micaceous sandstone, in some instances stratified, and in others possessing a slaty structure. In this bed are numerous vertical stems traversing all the strata, and appearing like a fossil forest of plants resembling the bamboo, or large equiseta, turned into stone, in the places where they 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 envelopement, or crust.

The other, and less common species, are hollow, cylindrical stems, spreading out from the base, like a root, but without ramifications.*

Many instances of this phenomenon occur in England, several of which are noticed by Mr. Witham, who has so materially contributed to our knowledge of the structure of fossil plants.† In the Derwent mines, at the depth of fifty-five fathoms, among numerous examples which were lying in horizontal layers, were several in an upright position. Two stems of *sigillariæ* were situated in the space cleared out to get at the lead ore, and stood upright, having their roots firmly impacted in a bed of bituminous shale; they were about five feet high, and two in diameter. In the Newcastle coal-field, in a stratum of sandstone 150 yards below the surface, are many erect stems of plants, having their roots in a thin layer of coal, as in this figure (Tab. 125). These plants are from two to eight feet in circumference.

19. TRUNKS OF CONIFERÆ IN CRAIGLEITH QUARRY.—In the quarry at Craigleith, near Edinburgh, at a depth of 140 feet, an enormous trunk of a tree was discovered about ten years since. The length was thirty-six feet, and the circumference of

* Notice sur des Végétaux Fossiles traversant les Couches du Terrain houiller, par M. Alex. Brongniart, à Paris. 1821.

† Observations on Fossil Vegetables, by Henry Witham, Esq. F.G.S. 1 vol. 4to. With Plates of the internal structure of fossil plants. Edinburgh, 1831.

the base nine. It lay in a nearly horizontal position, corresponding with the strata of sandstone in which it was imbedded. By polished transparent sections of the trunk, Mr. Witham was enabled to ascertain that this tree belonged to the coniferæ. A few years afterwards, another tree was found in this quarry. It was fifty-nine feet long, and lay at an angle of about 40°, traversing ten or twelve strata of sandstone. As is common in these fossils, the trunk was crusted with coal, probably the bark in a carbonized state.* In this beautiful section of the stem, from Craigleith, presented to me by my lamented friend, the late Dr. Henry, of Manchester, the coniferous structure is clearly displayed; and from this fact alone, the botanist can delineate the general form and foliage of the original tree, in like manner as the anatomist, from a few fragments of teeth and bones, is able to determine the affinities of the animal to which they belonged.

20. 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 globe. 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 between the eye and the light, is of a rich brown colour, and

* This specimen is represented by Mr. Fairholme in the situation it occupied in the quarry.

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* (Tab. 122, fig. 2), 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. My specimens, as you perceive, are reduced to mere films or pellicles.* 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.

21. NATURE OF COAL.—I advance to the examination of the substance called *coal*, which is vegetable matter, transmuted by chemical changes

* There are beautiful figures of these objects in Mr. Witham's work; and also in Dr. Buckland's Bridgewater Essay.

into carbon, and still exhibiting the structure of the plants from which it was derived. When sections of coal, obtained by the process above described, are viewed through the microscope, the fine, reticulated structure of the original is distinctly visible, the cells of which are filled with a light, amber-coloured matter, apparently of a bituminous nature, and so volatile as to be readily expelled by heat, before the texture of the coal is destroyed.*

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 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

* Mr. Hutton.

† Organic Remains of a Former World, vol. i. p. 181.

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 bitumination, stems and branches have been converted into brown coal, lignite, jet, coal, and anthracite.

22. MINERAL OIL, NAPHTHA, AND PETROLEUM.—I proceed to examine some of those substances which result from changes effected in vegetable matter during its mineralization, and will first notice those bituminous fluids which are commonly known by the name of mineral oil. Springs or wells of this inflammable substance occur in England and many other countries, as Persia, Calabria, Sicily, America, &c., and generally in rocks associated with coal. *Naphtha* is nearly colourless, and transparent, burns with a blue flame, emits a powerful odour, and leaves no residuum. Genoa is lighted with

naphtha from a neighbouring spring. *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 appears therefore 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 also 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 the subject of so much interest and investigation. The mineral oil may be ranked with amber, succinite, and other similar bodies which occur in the strata of the earth. The occurrence of petroleum in springs does not seem to depend on combustion, as has been supposed, but is simply the result 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 heat 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 enable us to collect it from wells, as in various parts of Persia and India.* The author of an interesting paper in the American Journal of Science, states that petroleum is now daily discharging into the soft mud and gravel in the beds of the Muskingum and Hews's rivers. At Chilley, in the county of Sussex, beds of sand are permeated throughout with bituminous oil, originating either from neighbouring peat-bogs,† or from lignite beds of the wealden.

23. BITUMEN, AMBER, AND MELLITE.—Bitumen may be described as an inspissated mineral oil; it is generally 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 specimens possess the colour and transparency of amber: the soft bitumens may be rendered solid by heat.

From the bituminous substances which I have placed before you, we pass by an easy transition to *Amber;* for black amber bears, both in its appearance and composition, a close resemblance to

* Dr. Reichenbach.

† Fossils of the South Downs, p. 76.

the solid bitumens. The nature of common amber is too well known to need remark; its electrical properties, odour, combustion, and the fact of its inclosing insects, leaves, and other foreign bodies, indicate its origin and former condition. This substance is found in nodular masses, which are sometimes eighteen inches in circumference; it occurs in beds of lignite, and on the coast of Prussia in a subterranean forest, probably of the newer tertiary epoch. Mr. G. B. Sowerby mentions having seen, at Baden, the branch of a tree converted into jet, the centre being filled with amber.* In the brown coal of Muskaw, amber occurs in the fossil coniferous wood, partly in disseminated portions, and *partly in the resin-vessels themselves;* and fir-cones are frequently discovered which contain this substance on and between the scales. Amber has also been found in coniferous plants associated with ferns, in coal that is referred to the upper secondary formations. There can be no doubt that amber is an indurated resin, derived from various coniferous trees, and which occurs in a like condition in all zones, because its usual original depositories, the beds of brown coal, have been formed almost everywhere under similar circumstances.†

A mineral substance, called *Mellite*, or honey-stone, from its colour, is found among the bituminous

* Phillips's Mineralogy, p. 374.

† M. Goppert; Jameson's Edinburgh Journal.

wood of Thuringia.* In its chemical composition, and electric properties, it bears a great analogy to amber; it is usually crystallized in small octahedrons. In the tertiary beds of Highgate a fossil resin, resembling copal, has been discovered.

24. THE DIAMOND.—The chemical constituents of the substances I have described are chiefly carbon or charcoal, and hydrogen, with a small proportion of oxygen—the essential characters of vegetable matter. In the diamond we have the elements of pure carbon; at a heat less than the melting point of silver, it burns, and is volatilized, yielding the same elementary products as charcoal. Sir Isaac Newton long since 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 has 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,

* Organic Remains of a Former World, vol. i. Pl. 1, fig. 2.

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.* The matrix of the diamonds of Southern India is the sandstone breccia of the clay-slate formation. Capt. Franklin observes that in Bundel Kund, diamonds are imbedded in sandstone, which he supposes to be the same as the new red sandstone, for there are at least 400 feet of that rock below the lowest diamond beds, and strong indications of coal underlying the whole mass.†

25. ANTHRACITE, OF CULM, CANNEL COAL, PLUMBAGO, OF GRAPHITE.—The coal commonly used for domestic purposes in this country is bituminous coal; containing, as before stated, a volatile, inflammable fluid, in a cellular structure. The culm, stone-coal, or *anthracite*,‡ as it is termed, appears to be coal deprived of its bitumen; for it is well known, that when basalt is in contact with coal, the latter is in the state of anthracite; and

* Geological Translations, vol. iii. p. 459.

† London and Edinburgh Journal, October 1835.

‡ Anthracite, derived from the Greek, and signifying carbon.

in some instances is even converted into plumbago, the substance of which black-lead pencils are constructed. Anthracite generally occurs in rocks of an earlier date than those which are strictly comprised in the carboniferous group; but it is convenient to notice the nature of the rock in this place, in connexion with the substance of whose vegetable nature no doubt can exist. By a series of interesting experiments, Dr. MacCulloch has shown that there is a natural transition 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 also has disappeared, and carbon only, or chiefly, remains. With this general explanation of the various states in which carbonized vegetable substances occur, I pass to the consideration of the process of petrifaction, that wonderful operation by which the most delicate animal and vegetable structures are converted into solid rock.

26. NATURE OF PETRIFACTION.—In many instances, we find a mere substitution of mineral matter for the original animal or vegetable matter. Such are those casts of sandstone, indurated clay, and other consolidated materials, which bear the forms and impress of organic bodies, but possess neither the internal structure, nor any vestige of the constituent substance of the original. The casts and impressions of shells, of the stems and leaves of plants, and of fish-scales; and the flints,

which derive their form from echinites, &c., are familiar examples of this process.

In genuine 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 into silex both of animal and vegetable substances, must, in the majority of instances, have been almost instantaneous, for the most delicate parts, those which would undergo decomposition with the greatest rapidity, are often preserved; such, for instance, as the capsule of the eye, the membranes of the stomach, the soft bodies of mollusca; and in plants, the cellular and vascular tissue. The fact of the silicification of trees in loose sand, and of the bodies of mollusca in their shells, as in these fossil oysters from the chalk at Brighton, while neither the sand nor the shells are impregnated with silex, cannot be explained by the infiltration of a silicious 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 develops itself only upon the organic substance of the animal; and that where such substance is not present, no silicification 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 subtle gas may acquire the greatest solidity; as, for example, in the union of oxygen with metallic substances.

27. ARTIFICIAL PETRIFACTIONS.—M. Goppert has published the result of an interesting investigation of the condition of fossil plants, and the process of petrifaction. Layers of ironstone nodules are very 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, 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; very commonly a leaf of a fern (as in Tab. 123, fig. 1, 2). Mr. Parkinson had remarked, that the leaf in these nodules might sometimes be separated in the form of a carbonaceous film; and M. Goppert

* See Pidgeon's "Cuvier on Fossil Animals."

† De la Beche, Researches in Theoretical Geology, p. 96.

having lately 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 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 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.

28. DIFFERENT STATES OF THE FOSSILIZATION OF WOOD.—A valuable communication on "Wood partly petrified by Carbonate of Lime," has recently been made to the Geological Society, by Charles Stokes, Esq.* 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. I cannot enter at length upon Mr. Stokes's interesting obser-

* Transactions of the Geological Society, vol. v. p. 207.

vations on this specimen, but his statement of the different conditions in which fossil wood appears, is highly important. Sometimes, he observes, 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 that the process began at an early period, and continued till the whole vegetable structure was transmuted into stone.* My lamented friend, Dr. Turner, in some admirable comments on the subject of petrifaction, remarks, 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

* Geological Transactions, vol. v. page 212.

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.

Mr. Parkinson, in corroboration of his opinion that wood undergoes bituminization before it becomes petrified, mentions, that a specimen of wood from Walton, which was changed into marble, and took a beautiful polish, left, upon removing the carbonate of lime by muriatic acid, a mass of light, inflammable, bituminous wood, which possessed a volume almost equal to its original state.*

29. Hazel-nuts filled with spar.—Before I quit this subject I would notice a singular fact—an instance of partial mineralization, in which mineral matter has permeated the shells of hazel-nuts, without altering their structure, although the interior is lined with spar. In Belfast Lough, a bed of submarine peat is situated beneath the ordinary level of the waters, but is generally left bare at the ebb tides. Trunks and branches of trees are imbedded in the peat, and vast quantities of hazel-nuts, the whole being covered by layers of sand, shells, and blue clay. On the east side of the Lough, limestone rocks exist, and the nuts in the peat contain calcareous spar. Some specimens are full, others are only lined with groups of crystals. The shells

* Organic Remains, vol. iii. p. 440.

of these fruits are entire, and have undergone no change, their substance being in the state of common dried hazel-nuts. On the west side of the Lough, the rocks are schistose, and the nuts, as is common in peat, are empty. The specimens in my collection, collected by Mr. Bryce, of Belfast, exhibit the different conditions I have described.

30. SILICIFICATION, OR PETRIFACTION 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 was also 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, and the lower portion of the cavity occupied by flint, the upper surface of the latter being covered by crystals of calcareous spar. The curious fact, mentioned in a previous lecture (p. 304), 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 of the echinus having undergone silicification; for the most organized parts are those which appear to have been

most susceptible of silicious petrification. In another specimen, in my museum, the oyster itself is turned into flint, while the shell is, as usual, carbonate of lime.* The shells of mollusca, the crustaceous skeletons of echini, and the bones of the belemno-sepiæ, appear to have possessed too little animal matter, and to have been too much protected by calcareous earth, to have become silicified; they are changed into spar by water charged with carbonic acid gas, having insensibly effected the crystallization of their molecules.†

* See an interesting essay on this subject, by M. Alexandre Brongniart, "*Essai sur les Orbicules Siliceux, &c.*" Paris, 1831.

† Mr. Reade's highly important experiments and observations on the structure of plants, appear to throw a new light on the silicification of wood. Mr. Reade states that "by the agency of heat the surrounding silicious matter may be liquefied, and the carbon and 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 silicious 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 silicious 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,

31. PLANTS IN AGATES, &c.—While treating of the silicification of organic remains, I must not omit to notice the occasional occurrence of the most delicate vegetables in those beautiful modifications of silex, or flint, called agate and chalcedony. The *mocha stones*, as they are termed by the lapidaries, frequently contain arborescent stains and markings produced by metallic oxides, as iron, manganese, &c.; and the mineral called *chlorite*, which is of a green colour, often assumes an appearance so like a plant as to deceive the inexperienced observer. But Dr. MacCulloch, M. Daubenton, and others, have proved that some of the arborescent appearances in chalcedonies are

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 all 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.

unquestionably fuci, confervæ, and other marine plants, which have become involved in the silicious nodule when it was in a fluid state, by which both the colour and form have been preserved in all the freshness, and disposed in as fine a manner, as if the plants were still living and floating in their native element.*

I have dwelt at considerable length on the processes by which animal and vegetable structures have been mineralized, and preserved in the strata through indefinite periods of time; and you will not, I trust, consider that this deeply interesting inquiry has occupied too much of our attention. In an earlier stage of our geological argument, I was unwilling to enter upon its consideration, lest our minds should not have been prepared to comprehend or relish an investigation of this nature. I proceed to the examination of the flora of the ancient world, entombed in the carboniferous strata.

32. PLANTS OF THE COAL FORMATION.—The beds of coal, as we have already seen, are wholly composed of fossil vegetables, stems, branches, leaves, &c.; and possibly the different kinds of coal may, as Mr. Reade has suggested, have resulted from original differences in the vegetables whence they were derived. The coal shales, or slates, are highly charged with carbon, a character which M. Goppert's experiments tend to elucidate; and

* See Geological Transactions, vol. ii. page 510.

they contain, as I have previously remarked, a profusion of fossil plants. The vegetable remains in the coal strata are almost universally 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 exemplified in this splendid series of specimens from Coalbrook Dale, for which I am indebted to John Pritchard, Esq., of Brosely. Brilliant sulphuret of iron, or pyrites, in some examples, permeates the entire vegetable structure; 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.* In the sandstones, the vegetable stems have generally a carbonaceous crust, and their structure is sometimes found in a calcareous or silicious state.†

The coal plants, which have been accurately determined, amount to upwards of three hundred; of these, two-thirds are related to the arborescent ferns, and the higher tribes of the cryptogamia; about ten species to the flowering monocotyledonous trees; as many to the coniferæ, and cactaceæ; and numerous species still remain undescribed. I will now

* Sulphuret of zinc—*blende* is a German term, signifying glistening.

† *Vide* Organic Remains of a Former World, vol. i.

place before you a few of the usual forms that occur in the British coal-measures, which will serve to convey a general idea of the nature of the carboniferous flora all over the world; for it is a remarkable fact, that the fossil plants found in the coal mines of Europe, are for the most part perfectly identical with those that occur in the coal of North America, Australia, and even of Greenland; all belonging to the same genera.*

33. FOSSIL MARE'S-TAIL, OR EQUISETUM.—The mare's-tail (*equisetum fluviatile*) of our marshes and ditches, is an elegant plant, having a succulent, erect, jointed stem, with attenuated foliage growing in whorls around the joints, the latter being protected by a distinct striated sheath; the parts of fructification constitute a scaly catkin at the apex of the stem. There are ten species of this genus, eight of which are natives of England; the stem of the largest does not exceed half an inch in diameter. In the coal-measures remains of this genus occur in abundance, and are referable to many gigantic species, some of the stems being fourteen inches in diameter. The *equisetum columnare*, a fossil of constant occurrence in the carboniferous strata, is beautifully figured and illustrated by M. Ad. Brongniart.†

34. FOSSIL FERNS (Tab. 123).—The *brake*, or fern, of our commons and waste lands, is a familiar

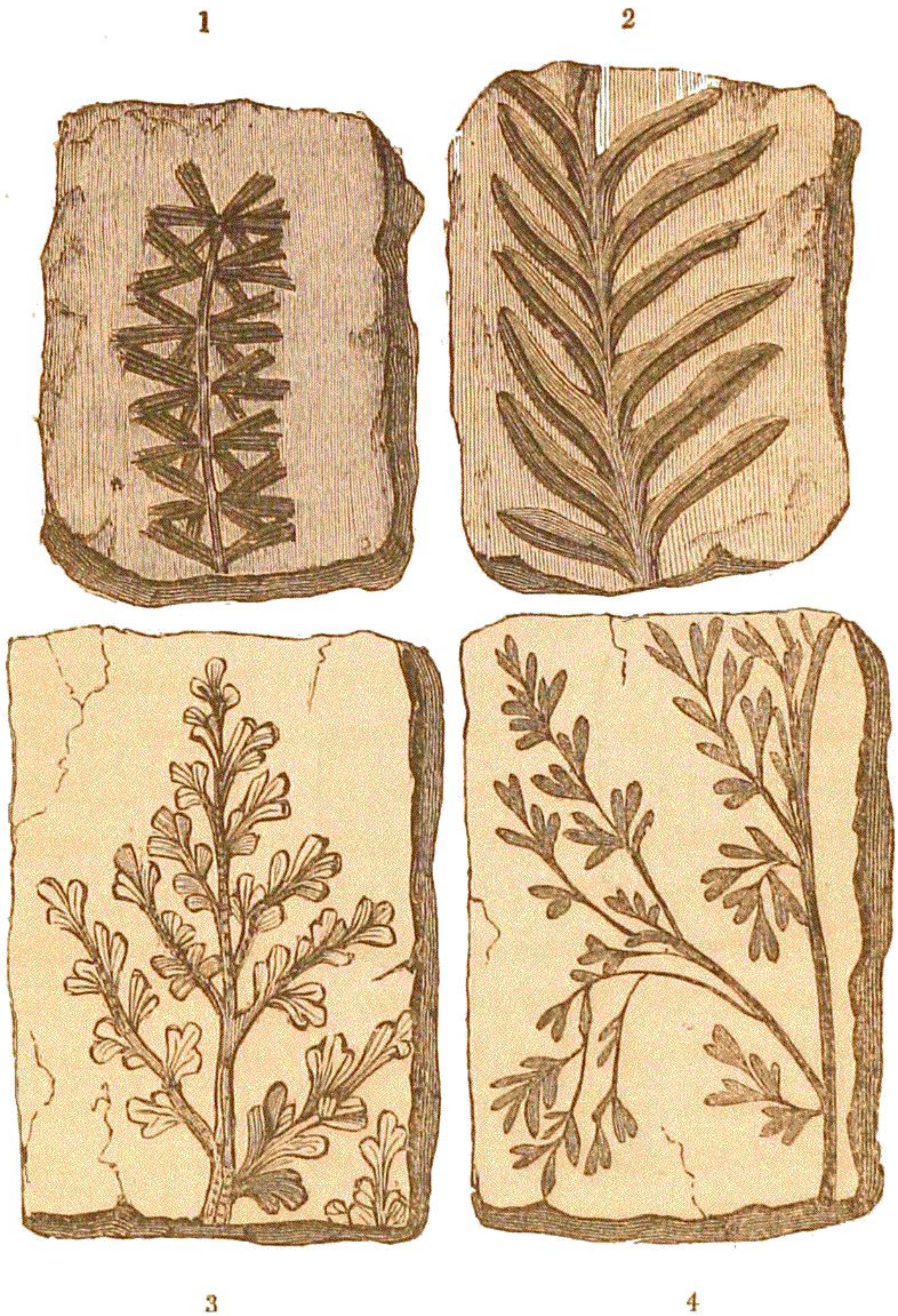
* Adolphe Brongniart, Prodome d'une Histoire des Veg. Foss.

† Végétaux Fossiles, tom. i. pl. 13.

example of a remarkable and numerous family of plants, distinguished by the peculiar distribution of the 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 (Tab. 129, fig. 5). The leaves of the smaller species are very elegant, and present immense variety in their forms, and in the modes of distribution of the veins of the leaf; 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 strata, is shown in the numerous specimens before us (see Tabs. 123, 124.) The fructification on the back of the leaf is sometimes distinctly visible (Tab. 74).

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 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 130 known species of ferns, nearly all of which belong to the tribe of polypodiaceæ; the

* Végétaux Fossiles, tom. i. pl. 37.



TAB. 123.—PLANTS OF THE COAL-MEASURES.

Fig. 1. Asterophyllites Parkinsoni, in coal shale. 2. Pecopteris Mantellii, in a nodule of iron-stone. 3. Sphenopteris linearis. 4. S. affinis, from Burdie House, by Dr. Hibbert.

common polypody, so frequent on the walls of old buildings, will convey an idea of the general character of the foliage. In speaking of the stems of ferns, I must remind you of the fossil plant from the Wealden, the *clathraria Lyellii* (page 374), in which the scorings on the outer surface, from the removal of the petioles, bear an analogy to those of the stems of tree-ferns and palms; but the internal axis, so well shown in the specimen (Tab. 75), separates it from those families.

TAB. 124.—SIGILLARIA (TREE-FERNS), AND FERN, FROM THE COAL.*

(One-fourth the natural size.)

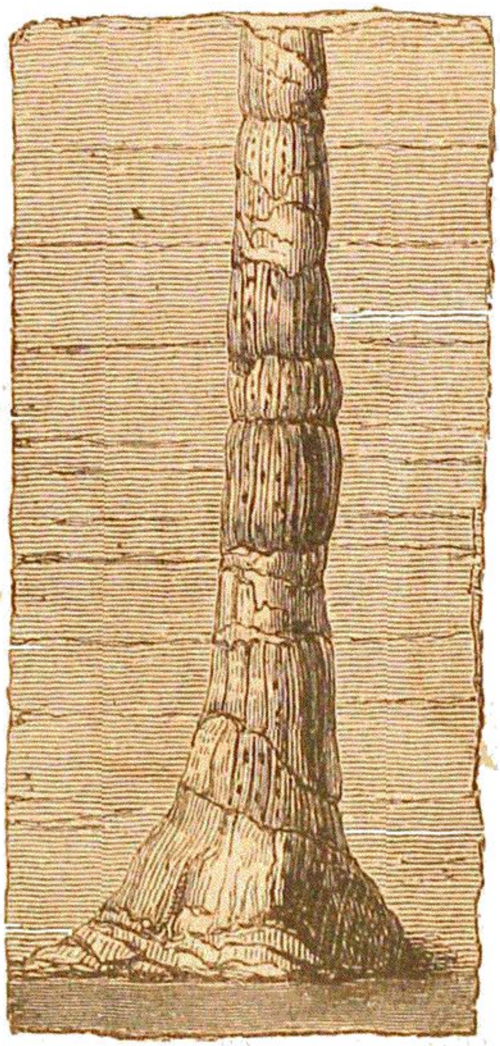
Fig. 1. Sigillaria Voltzii, from the anthracite of Baden; *a* the external surface; *b* the inner surface, a portion of the outer bark being removed. 2. Sigillaria Sillimani: from the coal mines of Pennsylvania. 3. Pecopteris Miltoni; a specimen showing the young frond before it expanded, still coiled up like a crosier.

35. SIGILLARIA† (Tab. 124).—Among the most common fossils that strike the attention of the

* M. Adolphe Brongniart. Veget. Foss.

† So named from the impressions on the surface.

observer in coal mines, are long, flat, fluted slabs, marked with impressions, disposed with great regularity, and presenting an infinite variety of patterns. (Tab. 124, fig. 1, 2). These are the compressed, cylindrical stems of plants related to the arborescent



MAIN COAL SEAM.

TAB. 125.—SIGILLARIA PACHYDERMA; A FOSSIL STEM, TEN FEET HIGH.

(*Drawn by Miss Ellen Duppa.*)

ferns; the imprints being the scars left by the leaf-stalks. No foliage has been found attached, but it is probable that many of the leaves so abundant in the shales belong to them. The stems vary from a few inches to three feet in circumference, and specimens have been discovered that indicate a length of sixty feet.

The stems often escape compression, and stand perpendicularly, intersecting the horizontal strata, sometimes 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 (Tab. 125), and two feet in diameter at the base. Its roots were in shale, immediately above a bed of coal, and the trunk extended through several strata of shale and sandstone. The sigillariæ were evidently hollow, like the reed, and with but little substance, as is proved by the extreme thinness of the specimens, which lie in a horizontal position, and are compressed. The upright stems consist entirely of sandstone, within the envelope of coal. Nearly fifty species are enumerated by M. Brongniart. The original trees appear to have been closely related to the arborescent ferns, but their leaves were small, and differently disposed than in any existing species.

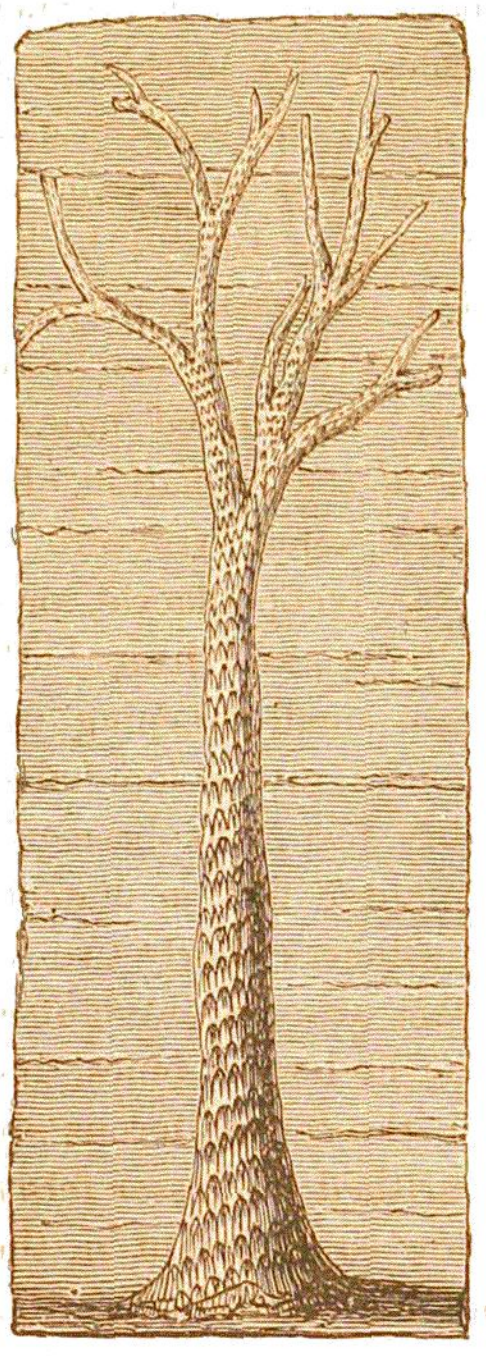
* The Fossil Flora of Great Britain.

Stems of several other genera of plants are found in the coal, the form and distribution of the markings of the leaves being very dissimilar to those I have described.*

36. Lepidodendron (Tab. 126). — The most elegant and abundant of the fossil plants of the coal are the lepidodendra, so named from the scaly appearance of the stems, produced by the separation of the leaf-stalks. The scars are simple, lanceolate, rhomboidal, and arranged spirally around the stem; the latter is slight and tapering, and sometimes arborescent. The cones, or *stroboli*, so common in the ironstone nodules, are the fruit of these elegant trees. In the markings on the stems, the lepidodendra resemble the club-mosses (*Lycopodiaceæ*), which are herbaceous, prostrate plants, found in damp woods and bogs, having their leaves simple and imbricated—that is, lying over each other; the tropical species, which are the largest, do not attain a greater height than three or four feet.

Count Sternberg remarks, that we are unacquainted with any existing species of plant, which, like the lepidodendron, preserves at all ages, and throughout the whole extent of the trunk, the scars formed by the attachment of the petioles, or leaf-stalks, or the markings of the adhesion of the leaves themselves. The yucca, dracæna, and palm, entirely shed their scales when they are dried up, and there only remain circles, or rings, arranged round the

* See Dr. Buckland's Bridgewater Essay, vol. ii.



TAB. 126.—LEPIDODENDRON STERNBERGII.

A fossil tree, thirteen and a half feet wide, and thirty-nine feet high.

(Drawn by Miss Ellen Duppa.)

This figure, from the Fossil Flora of Great Britain,* represents a specimen nearly forty feet in length, which was discovered in the Bensham coal seam, in the Jarrow coal-field. The width of the base was thirteen and a half feet.

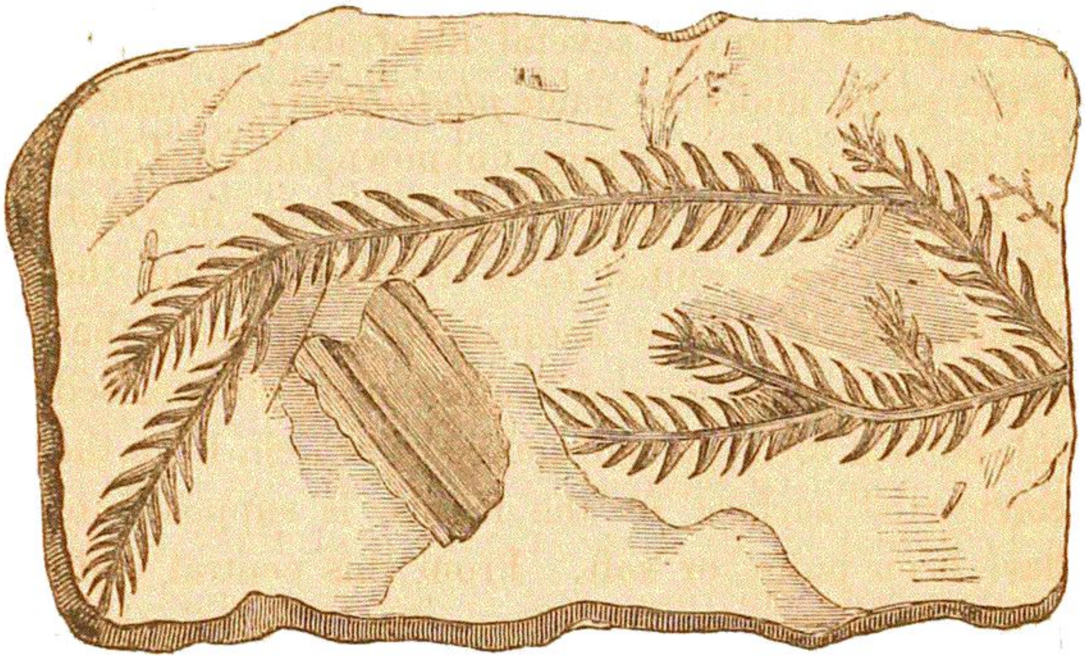
* Plate 203.

trunk in different directions. The flabelliform palms preserve their scales at the inferior extremity of the trunk only, but lose them as they increase in age; and the stem is entirely bare, from the middle to the superior extremity. But in the lepidodendron, the scales follow a decreasing proportion from the base of the trunk to the extreme branches.* The lepidodendra have contributed more than all the other vegetables to the formation of coal. Their trunks present the same structure and mode of ramification as the lycopodiaceæ, or club-mosses; and bear similar leaves and fruits. But while the recent species are small creeping plants, clothed with diminutive foliage, the lepidodendra attained a height of eighty feet; the base of their trunks being more than three feet in diameter, and their leaves in some instances nearly two feet in length. They were in fact arborescent club-mosses, comparable in size to the largest pines, and formed extensive forests in the carboniferous epoch, beneath whose shade flourished the lesser ferns, the remains of which are now so abundant in the coal-shales. Dr. Lindley and Mr. Hutton describe these plants as constituting a gradation from the flowering to the flowerless tribes.

37. Fossil club-moss (Tab. 127).—In a specimen from the Tyrol, with the precise locality of

* "Faut-il ranger ce genre d'arbres parmi un groupe de végétaux, qui aujourd'hui est indigène seulement entre les tropiques, et dont la végétation exige un climat plus doux et une température plus élevée?"—*Sternberg*, Flora zur Vorwelt.

which I am unacquainted, the characters of the lycopodiaceæ are beautifully displayed. The plant is in the state of carbon, or rather of indurated bitumen, and its dark tint admirably contrasts with



TAB. 127.—LYCOPODITES BENETTIÆ.*

(*Fossil club-moss.*)

(Drawn from nature, by Miss Ellen Duppa.)

the cream-coloured shale in which it is imbedded. Several species of lycopodites are described as occurring in the coal of Newcastle, and of Silesia.

38. STIGMARIA.—Very few traces of any but land plants have been observed in the coal strata;

* This elegant plant is named in honour of 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.

there is, however, one remarkable exception. A frequent fossil in the Derbyshire strata is a compressed sub-cylindrical stem, having the surface spirally studded with tubercles, and containing internally an imbricated body, or core. The late Mr. Martin * figured several illustrative examples of this plant, under the name *phytolithus imbricatus:* but its true characters were unknown, till Dr. Lindley and Mr. Hutton discovered specimens, in which the stems were united to a trunk.† From the observations of these naturalists, it appears that the plant had a central trunk, of a compressed sub-conical form, the substance of which, from the corrugated surface in the fossils, is supposed to have been pulpy or soft. From this central body proceeded from ten to fifteen branches, disposed horizontally, and dividing at unequal distances; when perfect, it is computed they would have extended twenty or thirty feet. The fossil stems are fragments of these branches, the tubercles being the bases of cylindrical, succulent leaves, many feet in length; the internal axis of which I have spoken, like that of the *clathraria Lyellii* (page 374), being the woody pith or core. The external hollow cylinder is entirely composed of spiral vessels. The stigmaria was probably an aquatic plant, inhabiting swamps or lakes, and

* Petrifacata Derbiensia.

† Fossil Flora of Great Britain, vol. i. page 93.

resembling the euphorbiaceæ in its internal structure.*

39. SEED-VESSELS IN COAL.—Seed-vessels occur in the carboniferous strata, and one species (Tab. 128) is not uncommon, but its natural affinities have not been determined. Among the numerous plants which I have omitted to notice, in this rapid sketch of the flora of the coal, is an extinct genus that differs altogether from existing types. It is called *asterophyllites*, from the verticillate arrange-

TAB. 128.—SEED-VESSELS FOUND IN COAL.

(*By W. D. Saull, Esq. F.G.S.*)

ment of the foliage (Tab. 123, fig. 1), and is supposed to belong to the dicotyledonous class.

40. CONIFERÆ.—Our previous investigation of the structure of the recent coniferæ (page 624) renders it unnecessary to explain the manner in which the nature of the fossil stems and woods can be determined. Mr. Witham, by microscopic observations on polished sections of fossil wood,

* Figures and descriptions of this plant are given by Dr. Buckland, Plate 56, page 477.

has proved the existence of several species of coniferous trees in the coal strata of Scotland; and similar examples have since been discovered in other carboniferous deposits. It is not a little curious that all the species are related to the araucaria, or Norfolk Island pine, and not to the common coniferæ; this is proved by the ducts of the vessels being arranged alternately, and in double and triple rows (see page 625). The pines 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 as little diversity, and that the changes of temperature were not abrupt.* It is said that in the coal of Nova Scotia and New Holland, coniferæ with the ordinary structure occur.

41. Review of the carboniferous flora.—A more extended notice of the fossil plants of the carboniferous system is not within the scope of these lectures, and I will now offer a brief review of the principal facts that have been submitted to our notice. We have seen that the striking character of the flora of that incalculably 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

* Witham.

associated a few palms, coniferæ allied to the araucariæ, 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 the most remarkable botanical feature: thus we have plants related to the mare's tail (*calamites*), eighteen inches in circumference, and ten or twelve 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 secondary formations, and that of the present day. The restoration of some of the vegetable forms which flourished in the carboniferous era, will perhaps prove more illustrative of this phenomenon than mere description. (See Tab. 129.)

To arrive at any satisfactory conclusions as to the nature of the countries which supported the plants of the carboniferous strata, we must consider the geographical distribution of the related existing genera, and the circumstances which conduce to their full development. It is now 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 the ferns and other cryptogamic plants; low islands in tropical latitudes being the localities

TAB. 129.—THE FLORA OF THE CARBONIFEROUS EPOCH.

(*Designed and drawn by Miss Ellen Maria Mantell.*)

Fig. 1. Auracaria. 2. Asterophyllites comosa. 3. Pandanus. 4. Equisetum. 5. Arborescent fern. 6. Fern. 7. Calamites. 8. Lepidodendron. 9. Sphenopteris.

where these forms of vegetation flourish most luxuriantly. We may therefore infer that the plants entombed in the coal strata, grew in a climate of at least as high a temperature as that of the tropics, and probably in insular situations; thus we obtain evidence of the existence during the carboniferous epoch, of a tropical Polynesia clothed with forests of palms, tree-ferns, and gigantic equisetaceæ and lycopodiaceæ.

42. FORMATION OF NEW COAL-MEASURES.—Let us now inquire 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 appear to have been almost wholly excluded—and whether accumulations of vegetables, which in after ages shall present phenomena of a like nature, are now in progress? We have seen that the plants in the coal-measures are for the most part lying horizontally, as if whole groves and forests had been laid prostrate, and become matted together, the smaller and more delicate tribes being entangled in the general mass; presenting, in fact, a very similar arrangement to that observable in the subterranean forests, peat-bogs, and other modern accumulations of vegetables. If we extend our observations to operations which are now going on in countries covered with a dense vegetation, abounding in lakes and marshes, and traversed by vast rivers, we shall no longer feel surprised at the immense quantities of vegetable matter which compose the coal-measures. In America, trees in prodigious numbers, the wrecks of whole forests, are

borne down by the tributary streams into the great rivers, and hurried along by the mighty flood of waters, till arrested in their course they become entangled, and form stationary masses called rafts, which in the Mississippi, and other large rivers of North America, extend over many leagues, and are of great depth: in some instances particular species are associated together, as cedars, pines, and firs, without the intermixture of other trees. Near the mouth of the Mississippi, rafts of great extent, composed of drifted trees brought down every spring, constitute a matted bed of vegetables, which is many yards in thickness, and stretches over hundreds of square leagues. These rafts become covered with fine mud and sand, on which other trees and plants are drifted down the following year; earthy deposits again take place, and thus alternations of vegetables with layers of calcareous matter are annually produced.*

In the lower plain of the Mississippi, immense inundations continually take place from the melting of the snow, and the flood of water thus suddenly poured into the bed of the river, and that of the Missouri. "The mouths of the large tributary rivers are thus absolutely choaked up, and their waters, being driven backwards, overflow their banks, and inundate the lower parts of the plain, forming lakes of twenty miles or more in length. Here we have the conditions required for the formation of future coal

* *Vide* Principles of Geology, vol. i.

fields: rapid development of vegetation in swamps, and periodical inundations of water charged with mud and sand."* That the bituminization of vegetables, and their subsequent consolidation by pressure into coal, might take place under the conditions here contemplated, we can readily conceive, from what is already known as to the conversion of peat into coal, in bogs of comparatively recent origin (page 48); but in the coal-measures we have vast alternations of strata that abound in marine remains. But rafts might be drifted into the tranquil depths of the ocean, and become covered with mud and sand; and a repetition of this process, at intervals, during a long period of time, would be sufficient to produce the appearances described. The occasional vertical position of the stems, and the admirable preservation of delicate leaves, do not appear to me to invalidate this inference; for in the entangled floating forests of the American rivers, trunks of trees often occur upright; and my distinguished friend, Admiral Sir Edward Codrington, informed me, that in the interior of the rafts, grasses and tender plants are often found entire. Such masses, therefore, might be drifted thousands of 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

* Bakewell's Geology.

durable forms like those which abound in the natural herbaria of the carboniferous strata.

43. CORALS AND CRINOIDEA OF THE CARBONIFEROUS SYSTEM.—But I must pass to the consideration of the animal remains entombed in the strata, which have afforded so rich and varied a field of botanical research. From the examination of the fossil corals and crinoidea in the previous lecture, a few remarks on this subject will suffice. About thirty species of polyparia occur in the limestones, but no traces have been observed in the coal measures. They consist principally of various species of tubiporæ and cateniporæ, cyathophylla, astreæ, turbinoliæ, and fungiæ (see Lecture VI. p. 570 to p. 575). Of the crinoidea, more than thirty species have been found. The mountain-limestone is the grand depository of the encrinites, and entire beds of marble are formed of their fossilized skeletons, as I explained in the former discourse (page 588). One singular genus of the crinoidea, *pentremites*, occurs in the carboniferous limestone of Derbyshire (Tab. 91, fig. 8): and I have also a species of the same genus from the United States, by Professor Silliman. One kind of cidaris (*C. Phillipsii*), with large mammillated tubercles, and muricated spines, has been found, and is the earliest known geological appearance of the family of echinodermata.

44. SHELLS OF THE CARBONIFEROUS SYSTEM.—The testaceous remains of above two hundred

species of the various families of mollusca have been collected. The ancient forms of terebratulæ (*brachiopodous mollusca*), which first appeared in the saliferous strata (page 474) abound in the mountain limestone; and in some localities the rocks are formed of spiriferæ, productæ, and terebratulæ, conglomerated by calcareous cement. Bivalves, comprising about ten fluviatile or fresh-water species, occur in some of the coal-measures, forming regular layers, called by the miners *muscle-bands*, from the character of 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 fresh-water strata. The nautili, ammonites, and other cephalopoda, amount to sixty species; and two very remarkable genera of this order appear:—the bellerophon (Tab. 91, fig. 4), which is a cephalopodous animal, having a shell without septa or partitions; and the orthoceras, or orthoceratite (Tab. 91, fig. 13). The latter may be described as a straight nautilus; it is a conical, chambered shell, having entire septa, pierced with a siphunculus; a reference to the remarks on the fossil nautilus will explain the nature and functions of this structure (see page 317). These shells are often of considerable magnitude; a specimen from Sweden, in my collection, is above twenty inches in circumference; and others are described as being two feet and a half in length, with sixty-six septa. Marbles, formed of these remains, also occur; and polished slabs afford interesting sections of the septa and siphunculus.

45. CRUSTACEA.—In viewing the zoological characters of the strata, in an ascending series, the remains of crustaceous animals next arrest our attention; and so many extraordinary forms of this family are met with in the carboniferous rocks, that in order to exemplify their nature, I shall briefly describe the structure and economy of the existing tribes.

Crabs and lobsters are familiar examples of this class of animals, whose skeletons are external, and whose circulation, respiration, and organs of locomotion, are very peculiar. They occur in a fossil state in the tertiary formations, as I have already mentioned; extinct species of lobsters, crabs, &c. being found in the beds of London clay near the metropolis, and in the isle of Sheppey. In the chalk, crustacean remains are comparatively rare; but my collection contains some beautiful examples of *astacidæ* allied to the cray-fish, from the South Downs; and several species and genera from the Galt.*

The Wealden exhibits no traces of this family,

* Geology of the South-East of England, p. 196.

with the exception of the minute cases or shields the cypris (page 380), which so largely contributed to the formation of the Sussex marble. In some localities of the oolite and lias, their remains are profusely scattered; the lithographic slates of Solenhofen alone have afforded to the researches of Count Munster nearly fifty species (page 450).

The crustacea, like all other tribes which are destined to live in water, perform respiration by certain external organs, termed *branchiæ*, which are formed by a peculiar modification of the external covering; these organs present great variety of structure and disposition, according to the habits and economy of the different species. In some kinds, as the crab and lobster, the branchiæ are fixed to the sides of the thorax, and inclosed in especial respiratory cavities; these organs consist of many thousands of minute filaments, like the fibres of a feather; and they are attached to short and flat paddles, which are kept in incessant motion by proper muscles, and thus the water is agitated, and its full action on the branchiæ maintained.

46. THE LIMULUS.—In another division of crustacea, the *limulus*, or king-crab, a genus abundant in the seas of India and America, the gills are disposed on lamelliform processes. The limulus has a distinct carapace or buckler, with two eyes in front of the shield. A small fossil species (Tab. 130)

is found in the ironstone nodules of Coalbrook Dale.

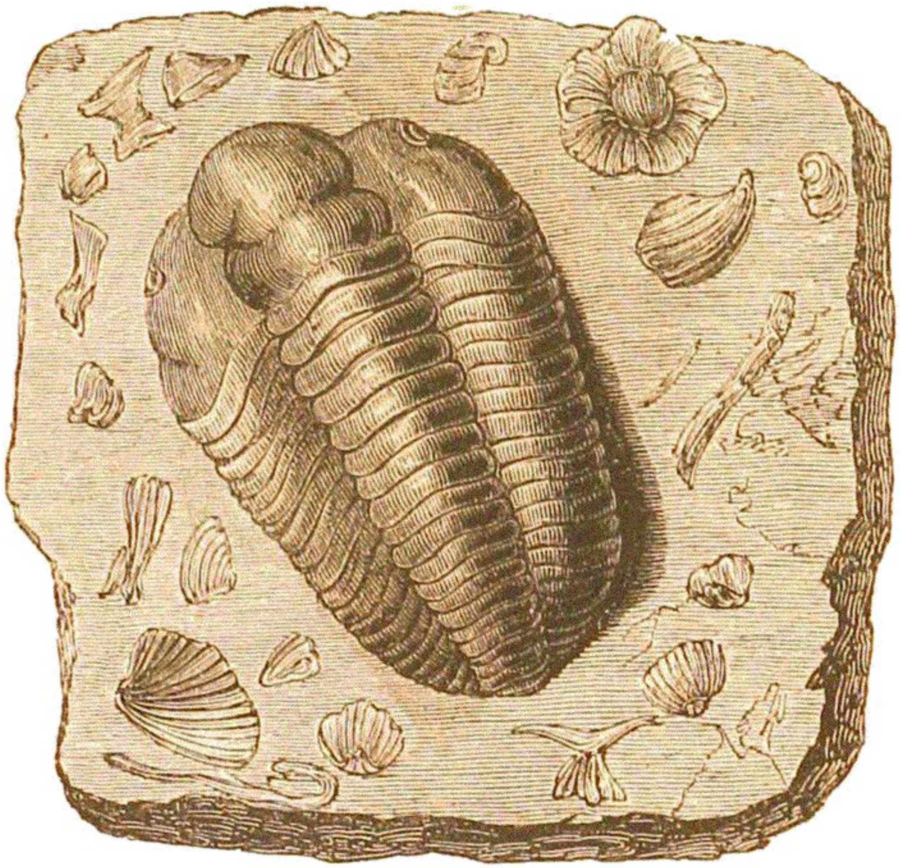
TAB. 130.—LIMULUS FROM COALBROOK DALE.

(Limulus trilobitoides.)

47. TRILOBITES.*—In the carboniferous strata we find those extraordinary forms of animal organization, which, under the names of Dudley locusts and trilobites, have long been known to naturalists and collectors. They belong to a family of the crustacea, which appears to have become extinct after the deposition of the coal, no traces of these remains having been discovered in rocks of a more recent period. The trilobites have been divided into ten or twelve genera, comprising nearly sixty species, and to which additions are constantly being made. Their general structure consists of a crustaceous shell, divided by longitudinal grooves, or

* *Three-lobed*, from their general form.

furrows, into three lobes, (hence the name,) and having segments which were capable of being folded



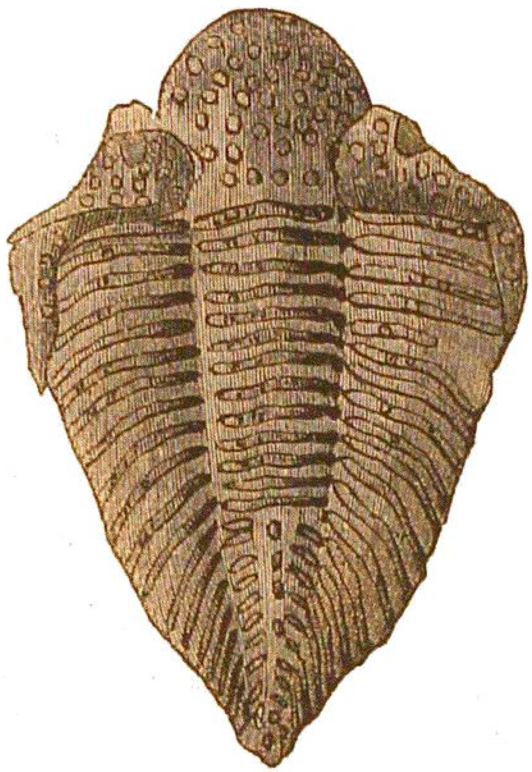
TAB. 131.—TRILOBITE FROM DUDLEY.

(Calymene Blumenbachii.)*

over each other. They vary exceedingly in form and magnitude; some species not exceeding a few lines, while others are a foot in length. Some species (Tab. 131) could coil themselves into a ball, like the millepedes; others had the central segments alone moveable (Tab. 132); and many were furnished with a tail, or postabdomen (Tab. 133).

* *Calymene*, concealed; alluding to the non-discovery of legs or antennæ.

As no traces of legs have been discovered, it is inferred that they possessed soft, perishable paddles,



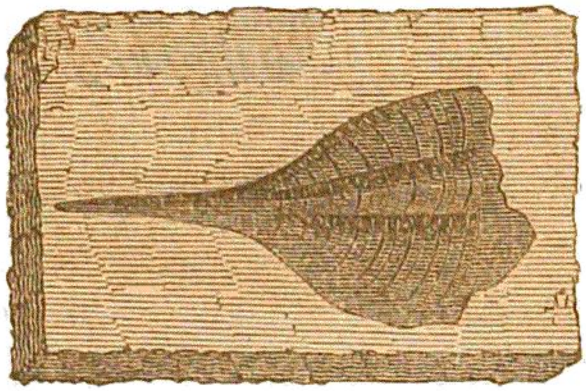
TAB. 132.—TUBERCULATED TRILOBITE, FROM DUDLEY.

(*Asaphus* * *tuberculatus.*)

bearing branchiæ. In the Silurian rocks, which are the grand depository of the trilobites, for but few species occur in the carboniferous, and none in the Devonian systems, Mr. Murchison has discovered nearly forty species, belonging to nine genera. Among these is a genus, named *homalonotus* by Mr. König, remarkable for the almost entire absence of the two lateral furrows that divide the body of the trilobite into three lobes, and thus confer on it its essential character.

* *Asaphus*, obscure.

The *homalonotus delphinocephalus* (Tab. 134) is a very extraordinary species that occurs in the Wenlock limestone; its whole surface is scabrous.



TAB. 133.—TRILOBITE WITH A TAIL, FROM DUDLEY.

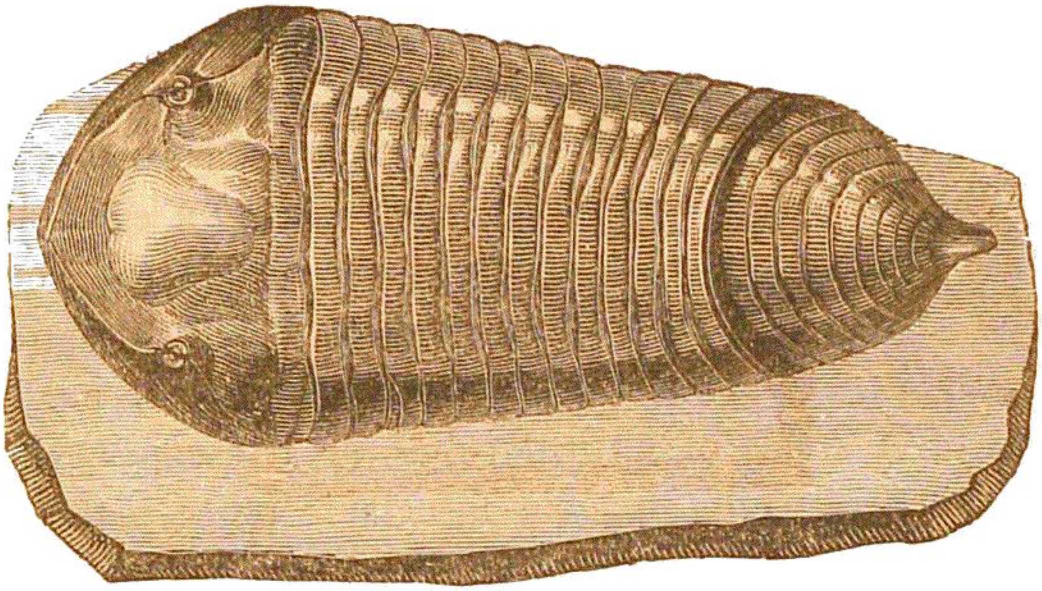
(*Asaphus caudatus.*)

With regard to the habits of these marine crustacea of the older rocks, Mr. W. S. Mac Leay * supposes, from the trilobites being closely allied to the recent *bopyrus*, and their feet being almost null, if not entirely so, that they were to a certain degree sedentary; the flat under surface of their bodies, and the lateral coriaceous margin of several species, which is so analogous to that of *chiton*,† render it probable that they adhered with a soft articulated underside to rocks or fuci. "Some species appear to be without eyes, and all without antennæ or distinct feet: if they had feet they must have been so small, membranaceous, and soft,

* Silurian System, p. 669.

† A multivalve shell so called.

as to be almost useless as organs of locomotion. That they were carnivorous is probable from the



TAB. 134.—TRILOBITE FROM THE LUDLOW ROCKS.

(*Homalonotus delphinocephalus.**)

structure of the mouth: and the highly organized eyes of some genera, prove that they had to search for food, and consequently some power of locomotion, for no truly sessile animal is provided with sight. The trilobites probably (like ostreæ, cocci, and other sedentary animals) adhered in masses one upon the other, and thus formed those conglomerations of individuals which are so remarkable in certain rocks."†

48. EYES OF THE TRILOBITE.—The structure of the eyes of the crustacea is similar to that of

* Reduced from Mr. Murchison's Silurian System, Plate VII. *bis.*

† Silurian System, p. 669.

insects, the nature of which was fully explained in my lectures on the nervous system. It will be sufficient to state, that the eyes of these creatures are immoveable, and that this apparent deficiency is compensated by a visual organ of a most extraordinary kind. The eye is 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 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 an animal, which must have perished 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 fur-

* See Dr. Roget's illustration of this subject; Bridgewater Essay, vol. ii.

† This structure of the eye of the trilobite was, I believe, first noticed by that accurate observer, Mr. Martin, the author of Pretif. 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, this subject, like every other which that eminent geologist investigates, is ably elucidated, and placed before the reader in a striking point of view.

nished with two compound eyes, each being the frustrum of a cone, but incomplete on that side which is opposite to the other eye. In the asaphus (Tab. 132), 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 crustacea. 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, 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 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 crustacea first existed in the bottom of the primeval seas, as at the present moment."*

49. INSECTS OF THE COAL FORMATION.—Several species of beetle (*curculio*) have been found in the

* Bridgewater Essay.

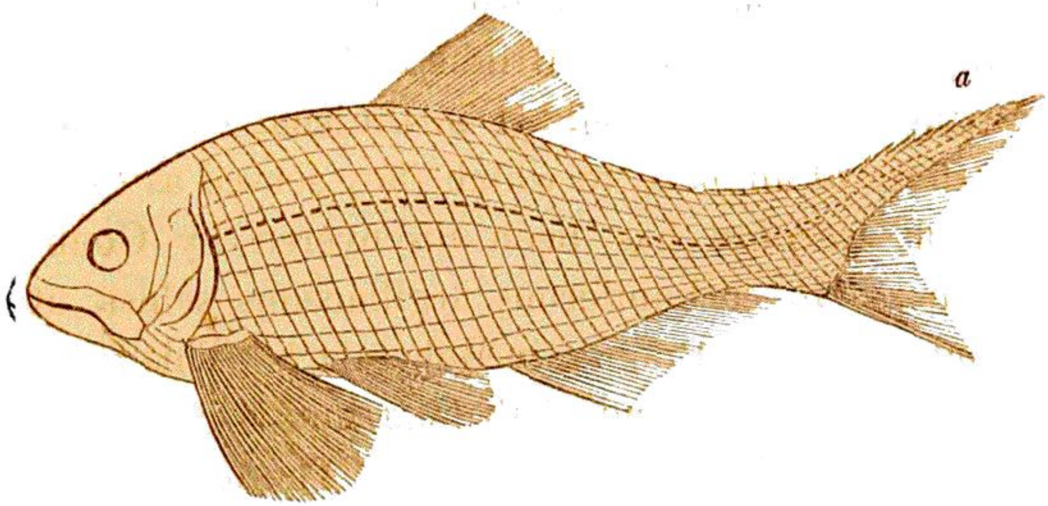
ironstone of Coalbrook Dale, and are figured by Dr. Buckland; my museum contains the wing of a neuropterous insect, closely resembling that of the living *corydalis* of Carolina; it is much larger than the wing of the largest dragon-fly.* This specimen is also from Coalbrook Dale; I discovered it, together with the *limuli* (Tab. 130) on the table, in nodules of ironstone, for which I am indebted to John Pritchard, Esq. of Brosely. 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 is composed, *elytrine*, having resisted decomposition and mineralization.

* This specimen is figured in Mr. Murchison's Silurian System, page 105, plate 13, *a*.

† See Dr. Buckland's Bridgewater Essay, plate 46, p. 406, *et seq*.

50. FISHES OF THE CARBONIFEROUS AND DEVONIAN SYSTEMS.—Although the remains of fishes are of comparatively rare occurrence in these formations, yet ten or twelve species, belonging to extinct and very remarkable genera, have been established by M. Agassiz.

The *amblypterus* (Tab. 135) is an extinct genus



TAB. 135.—RESTORED FIGURE OF AMBLYPTERUS; A FISH PECULIAR TO THE CARBONIFEROUS SYSTEM.

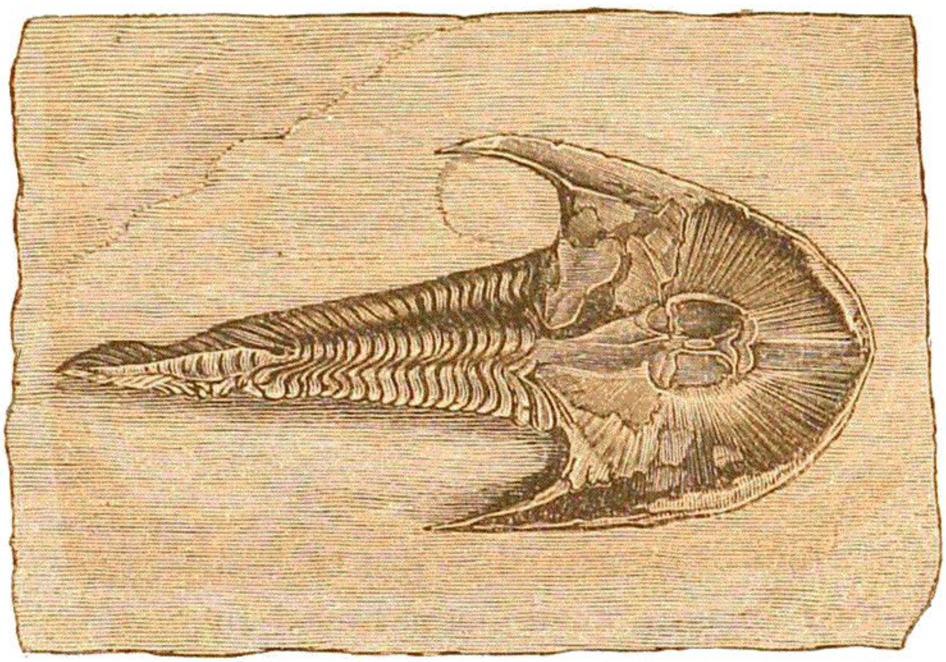
(*By M. Agassiz.*)

One-sixth the natural size.

of fish, which is restricted to the carboniferous system: four species have been found in nodules of ironstone at Suarbrück, in Lorraine; they also occur in similar nodules on the coast of Scotland, near Leith. From the character of the teeth, which are small, numerous, and set close together like a brush, these fishes appear to have fed on decayed sea-weed, and soft animal substances.* This ichthyolite furnishes an example of

* Dr. Buckland.

that peculiar structure of the tail, which M. Agassiz states is found in almost all the fishes that occur in the formations below the saliferous system. In existing fishes, the fin of the tail presents itself in three forms; rounded and single (as in the *macropoma*, Tab. 61, fig. 2); in two symmetrical lobes (as in *aulolepis*, Tab. 61, fig. 2); and double with the dorsal portion prolonged, the vertebral column extending into the produced lobe (Tab. 135, *a*) as in the shark, dog-fish, &c. It is this last form, which



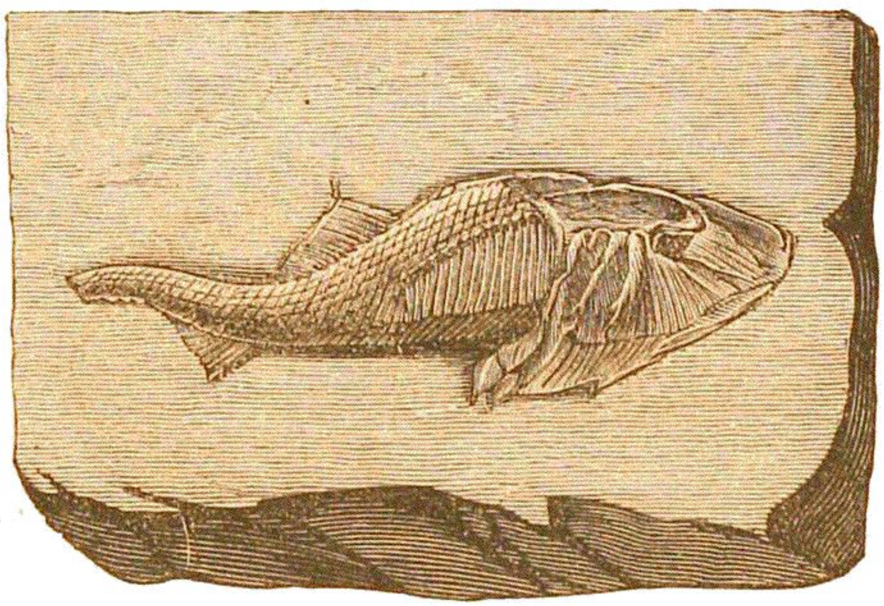
TAB. 136.—CEPHALAPSIS LYELLII: FROM GLAMMIS, IN FORFARSHIRE; A FISH PECULIAR TO THE OLD RED SANDSTONE SYSTEM.

(*Discovered by Mr. Lyell.*)

One-fourth the natural size.

belongs to the amblypterus (Tab. 135), and characterises the fishes of the older rocks; while in the fishes of the formations above the magnesian limestone, this structure is very rarely found.

In the old red sandstone beneath the carboniferous beds in Scotland, scales and other remains of fishes were discovered many years since by Dr. Fleming, to whom I am indebted for the specimens before us. These scales belong to an extraordinary fish that has been named *Cephalaspis* (*buckler-headed*) by M. Agassiz, from the head being covered by a buckler or shield, and the bones united into one osseous case. The scales form elevated bands, and the rays of the fins are covered by the membrane



TAB. 137.—CEPHALASPIS LYELLII; LATERAL VIEW, SHOWING THE PRODUCED DORSAL LOBE OF THE TAIL.

(*By M. Agassiz.*)

which elsewhere surrounds them. The fishes of this genus bear a general resemblance in form to the large elongated trilobites of the Silurian rocks; they are confined to the old red sandstone system. They were first discovered by the eminent philosopher whose name is attached to the principal species,* at Glammis, in Forfarshire; they occur also in Shropshire, Herefordshire, and other districts of England and Wales; and Mr. Murchison has traced their remains throughout the old red system of England and Scotland. The enormous size of the head, its crescent-like shape, terminating in two lateral horns or processes, and its lamellar structure, form so striking a resemblance to the shells of crustacea, that it is not surprising that disjointed portions should have been often mistaken for the remains of trilobites (Tab. 136, 137).

Another remarkable group of fishes, of these strata, is the *sauroid*, of which several gigantic species have been found by Dr. Hibbert, in the strata of Burdie-House. The teeth of these fishes are large striated hollow cones, bearing considerable resemblance to the teeth of crocodiles, with which they were formerly confounded. The scales are thick and strong. The tail, as in the fishes above described, is unequal, the vertebral column extending to the extremity of the upper or dorsal lobe. But I must not dwell longer on this division of our subject; the work of Mr. Murchison, which I have so often cited, and again shall repeatedly have occasion to notice, must be referred to for a more ample account of the ichthyolites of the carboniferous and Devonian systems.†

* Principles of Geology, fifth edition, vol. iv. p. 296.

† Silurian System, vol. ii, p. 585 to p. 601

51. RETROSPECT. — THE FLORAS OF THE ANCIENT WORLD.—In conclusion, let us review the botanical characters of the geological formations, as

1 2 3

TAB. 138.—PLANTS OF THE NEW RED SANDSTONE.

(Drawn by Miss Ellen Duppa.)

Fig. 1. Voltzia longifolia. 2. Voltzia brevifolia, with the fructification. 3. Filicites Scolopendroides.

indicated by the fossil vegetables hitherto discovered. In the transition rocks, hereafter to be described, about thirteen species of cryptogamic plants, four of which are sea-weeds (*algæ*) and the remainder ferns, comprise all that is known of the vegetable kingdom, anterior to the carboniferous system; no trace remaining of any additional tribes, which may have existed at that period.*

The carboniferous era, as we have seen, abounded in the vascular cryptogamia to a degree unexampled at the present time; the plants belong to species and genera now extinct, but allied to existing types by common principles of organization. The numerical preponderance of the cryptogamia in the coal is such, that while in the present order of nature they are to the whole number of known plants as one to thirty, at that epoch they were in the proportion of twenty-five to thirty. In the saliferous system, about fifty species have been ascertained, some of which differ from any observed in the coal-measures. They were discovered by M. Voltz, of Strasburgh (to whom I am indebted for the specimens before us), in the shale, or indurated marl, belonging to the new red sandstone at Sulz-les-bains. These fossils consist of a large species of equisetum, four species of ferns, and the frond of a plant bearing some resemblance to the common adder's tongue (*Scolopendrium*) so

* Fossil fuci abound in the transition 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.

common on the banks of our woods and hedge-rows. This specimen (Tab. 138, fig. 3) exhibits the back of the leaf, with the fructification. The other vegetables belong to a new genus of coniferæ, named Voltzia, from the discoverer (Tab. 138, figs. 1, 2). They approach the auracaria, or Norfolk Island pine.* Six species of fuci have been noticed in this formation. Here, for the first time, appear the plants allied to the cycadeæ.

In the oolite and lias we find coniferæ, liliaceæ, palms, ferns, and cycadeæ. The latter hold an intermediate place between the palms, ferns, and coniferæ. Some species are very short, as the *zamia;* others, thirty feet high, as the *cycas circinnalis.*† Leaves of cycadeæ are of frequent occurrence in the shale of the oolite near Scarborough, and several species have been obtained from the Stonesfield slate. The coniferæ of this epoch exhibit a condensation of the outer margin of each woody layer, denoting an increase of cold at the latter part of the autumnal season. In the oolite, the stems and fruit of a species of pandanus have been discovered. The pandanus, or screw-pine, (Tab. 129, fig. 3,) so named from the spiral arrangement of its leaves, abounds in the islands of the Pacific Ocean, and, with the cocoa-nut, is generally the first vegetable

* Essai d'une Flore du Grès bigarré, par M. Adolphe Brongniart.

† A *zamia* is introduced in the foreground of the Frontispiece. It somewhat resembles a pine-apple, with a tuft of leaves on the apex.

colonist of the coral islands. The fossil fruit was found in the inferior oolite, near Charmouth, and is now in Dr. Buckland's collection. It is of the size of a large orange, and is covered by a stellated rind, or epicarpium, composed of hexagonal tubercles, forming the summits of cells which occupy the entire surface of the fruit.* The fossil plants discovered in the oolitic system comprise four marine species, thirty-nine terrestrial cryptogamia, and forty belonging to coniferæ and other tribes.

The Wealden contains abundance of coniferæ and plants allied to the cycadeæ. One of its ancient forests preserved in stone, and in which the trees still occupy their original position, has been already submitted to our notice. Equiseta, ferns, cycadeæ, and plants allied to the palm, dracæna, thuya, and yucca, occur in Tilgate forest; at Hoër, in Scania, M. Adolphe Brongniart has discovered a similar flora.†

In the chalk we have the fruits and stems of

* Dr. Buckland's Bridgewater Essay, p. 503.

† Professor Römer, in his Versteinerungen des Nord deutschen Oolithen-Geberges (Hanover, 1836), points out the existence of the *Wealden* in Hanover, where it occupies a considerable area to the north of the Porta Westphalica, including the coal-field of Bückeburg, the impure coal of which is analogous to our Sussex lignite strata. After stating that this formation, which has a thickness of about 800 feet, lies upon the oolite, and dips under the green sand, (as was known to the late distinguished geologist Hoffman—the first, indeed, to suggest that the tract was occupied by an equivalent of the Wealden,) Römer enumerates many fossils which characterise in succes-

coniferæ, and of plants allied to the yucca. A stem discovered by Mr. Bensted in the Iguanodon quarry near Maidstone, appears related to the Sternbergia of the coal measures; the annular markings of the leaves resemble those of the yucca, or dracæna. Twelve species of fucus, two of conferva, and four of zostera, have been found in the chalk. Dicotyledonous wood, bored by the teredo and fistulana, and water-worn, is common in the line of junction between the galt and green sand. The distinctive character of the flora of the upper secondary formations is the prevalence of cycadeæ.

The tertiary deposits abound in palms and tree-ferns; and dicotyledonous trees prevail to a greater extent than in the secondary; these strata include

sion "der Ashburnham schichte," "der Hastings sandstein," and "der wälder-thon" (*weald clay*), including *cyclas, paludina, cyrena, cypris, &c.* with saurian remains.

It appears from a letter addressed by Professor Römer to Dr. Fitton, and recently read before the Geological Society, that the *Clathraria Lyellii* (see page 374) and other species named by me, have been identified by the German geologists; and my friend Mr. Murchison, who went over the ground some years ago, and who called my attention to Römer's work, assures me that he has no doubt of the accuracy of that author's determinations; and adds, that he saw upon the spot a fine specimen of tortoise found in sandstone very analogous to that of Hastings. Deposits which may be considered the equivalents of the Wealden were discovered in 1827 by Mr. Murchison and Professor Sedgwick on the east coast of the Highlands of Scotland, and last year similar strata were found by Mr. Malcolmson on the east coast near Elgin. It is even supposed that traces of this formation occur in some places near the Alps.

many terrestrial, lacustrine, and marine plants. Fossil fruits of existing genera, as pandanus, cocos, pinus, ulmus, acer, salix, &c., present the essential characters of the modern flora. The local accumulation of tropical plants and fruits in cold and temperate climates has been alluded to in the previous lectures, and is in accordance with the zoological character of the eocene epoch.

In the newer tertiary 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 (page 250) lie buried amidst beds of poplars, willows, maples, linden-trees, and elms;* and the brown coal of the Rhine (page 269) is composed of similar vegetables. 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 *chara* 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 inquiry enables us to establish, we perceive that, from the most ancient formation in which traces of vegetation remain, the sea has supported the usual orders of marine plants: and that on the land, ferns and other cryptogamia,

* See an interesting account of the fossil plants of Œningen, by Professor Braun, of Carlsruhe; Dr. Buckland's Essay, p. 510.

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 (page 568). The theory of the progressive development of creation receives no support from the state of vegetation in the early geological epochs, as Dr. Lindley has emphatically remarked; 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 other types of vegetation in the transition rocks must not however be received as proof that the flora of that period was thus sterile: the only legitimate inference, in the present state of our knowledge, is that the circumstances under which those strata were accumulated, were unfavourable to the envelopement or preservation of terrestrial plants. We have seen that the existing fundamental distinctions of vegetable structure prevailed also in the earliest secondary formations, a fact in accordance with what we observed in the animal kingdom: and the same unity of purpose and design is manifest in all the varied forms of organization that lived on our planet, through the vast range of time which geological investigations have enabled us to scan.

LECTURE VIII.

1. Introductory remarks.—In the former lecture the flora of the ancient world constituted the principal object of our investigations. 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 epoch of the

earth's physical history. The insects which fluttered among the tropical vegetation of that early polynesia, and the fishes and crustacea which abounded in 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." *

The wonderful transmutation into stone of the most delicate structures both of animals and vegetables; the mineralization of the complex visual apparatus of that ancient family of crustacea, the trilobites; and the evidence thus afforded of the actual condition and relation of the waters and of the atmosphere with light, at the period when the ocean swarmed with those singular beings, were considered and explained.

We now advance another stage in our eventful progress; and again we have to examine deposits which have been accumulating for innumerable ages in the basins of seas fed by rivers and streams, bearing with them the detritus of the strata over which they flowed, and imbedding the remains of the plants and animals that existed at the epoch 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

* Mrs. Howitt.

waters which deposited the marine strata of the most ancient beds previously examined; but altogether dissimilar to those of more modern eras. In vain may we seek for the remains of the mammalia of the tertiary period—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 Jura limestone—of the fish-like lizards of the lias—or of the tropical forests of the coal-measures—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 stinted 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 forms of animals and vegetables gradually disappear, while the shades 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 SILURIAN AND CAMBRIAN SYSTEMS.—By a reference to the chronological arrangement (page 194, and Pl. 7), it will be seen that arenaceous and argillaceous strata, with limestones, and an immense thickness of slate rocks, fill up the interval between the old red sandstone, or Devonian system, and the mica schist, which is the uppermost of the metamorphic or igneous crystalline rocks. The term *transition* was formerly applied to these formations (page 17); and also that of 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 Mr. Murchison, whose able and indefatigable researches have determined the true position, relation, and character of these deposits: the lowermost, consisting principally of slate rocks, has been named the CAMBRIAN SYSTEM by Professor Sedgwick, whose successful labours in this difficult field of geological inquiry have rendered clear and intelligible what before was doubtful and obscure.

* From the German *grau*, grey, and *wacké*, a name employed by the German miners to denote hardened conglomerates.

† Silurian—derived from the *Silures*, the ancient Britons who inhabited the country where these strata are most distinctly developed.

3. THE SILURIAN SYSTEM.—The Silurian system is well developed in the border counties of England and Wales, and spreads over a considerable area of South Wales, forming a link which connects the carboniferous series with the ancient slate rocks of that country. The strata are named and characterised by Mr. Murchison according to the following table:—

SILURIAN SYSTEM. (Plate IX. iv.)

(*Commencing with the uppermost.*)

Upper Silurian, thickness about 4000 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 marine shells, orthoceræ, spiriferæ, and trilobites. *Fishes.* *Wenlock*, or *Dudley limestone*—sub-crystalline blue and grey limestone — abounding in trilobites, crinoidea, polyparia, spiriferæ, orthoceræ, &c. *Wenlock shale*—dark-grey argillaceous shale, with nodules of sandstone.
Lower Silurian, thickness about 3500 feet.	*Caradoc* sandstone*—shelly limestones, and finely laminated, slightly micaceous greenish sandstones. Corals, mollusca, trilobites. *Llandeilo flags and limestone.* Freestone, conglomeritic grits, and limestones. Dark-coloured flags. Beds of schist with abundance of trilobites and mollusca.

Total thickness, nearly 8000 feet.†

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* *Caradoc*, or Caractacus, the celebrated British chief.

† The SILURIAN SYSTEM, founded on geological researches in the border counties of England and Wales, with descriptions

These beds are entirely of marine origin, and the limestone at Dudley and other places swarms with trilobites, crinoidea, corals, spiriferæ, productæ, and other fossils, with which our previous investigations have made us familiar. The subdivisions introduced are locally important; but a general analogy prevails in the organic remains throughout the rocks, 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.

Mr. Murchison has shown that each principal division of the Silurian system may be distinguished by peculiar fossils. Thus the upper Ludlow rocks contain scales, spines, fins, jaws, and teeth of fishes, and these are the most ancient beds in which any

of the coal fields and overlying formations; by *Roderick Impey Murchison, Esq. F.R.S.* &c. In two parts, royal 4to. with a separate map, and numerous illustrations. London, 1839; p. 768. This splendid work forms 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, are now shown to form a regular system, and to possess zoological characters as well defined as those which mark the newer secondary formations. The additions made to the geological fauna by Mr. Murchison comprise 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.

remains of that class have been discovered. Certain species of trilobites occur in one division of the formation, and are absent in the others; the *homalonotus* (Tab. 134) is restricted to the upper groups, and the *trinucleus* (of Murchison) to the lowermost; many species of shells, corals, and crinoidea have also stratigraphical limits.* It will suffice for our present purpose to state, that beneath the Devonian system there is an immense thickness of marine strata, composed of sands, sandstones, limestones, and conglomerates; some of which were originally coral reefs, while others are composed of the remains of crustacea and mollusca belonging to extinct species and genera. The slates of Dudley limestone before us, are made up of corals, shells, and trilobites, cemented together by indurated clay or mud; the strata from whence they were obtained appearing to have been formed in a manner similar to recent coral banks.

4. THE CAMBRIAN, OR SCHISTOSE SYSTEM (of Professor Sedgwick). Plate VII. fig. 9; Plate IX. fig. 2.—The Silurian formation 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 rocks. This system extends over a great part of Cumberland, Westmoreland, and Lancashire, reaching to elevations of 3000 feet, and giving rise to the grand scenery of the lakes and of North Wales.

* See Silurian System, vol. ii. p. 703.

Beds of this system flank the chain of the Grampians, and the range of Lammermuir, and occur in Argyleshire, and in the west of Scotland. In Ireland, slate borders the region of primary rocks. Wales may be described as a grand slate formation, with a considerable expansion of indurated conglomerates or greywacké. The slate district of Cornwall is well known. Charnwood Forest, part of Anglesea, and the Isle of Man, are formed of beds belonging to this system. The following tabular arrangement explains the relative position and characters of the subdivisions adopted by Professor Sedgwick :—

Cambrian, or Slate System of North Wales.

(*Commencing with the uppermost.*)

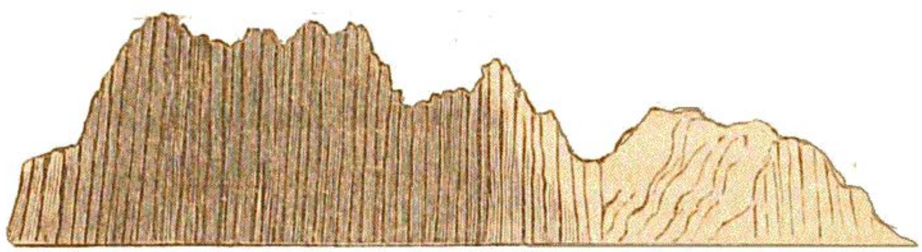
Plynlymmon rocks.—Grauwacké and slate, with beds of conglomerates. Thickness, several thousand yards.

Bala limestone.—Dark limestone, associated with slate, containing a few species of shells and corals.

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 (*cyathophylla*), and six of shells belonging to the ancient genera of the family *terebratula.* 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 is seen to pass into sandstone and grey-wacké.

5. THE STRUCTURE OF SLATE ROCKS. — 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.



TAB. 139.—SLATE ROCKS AT WHITESAND BAY, NEAR ST. DAVID'S, PEMBROKESHIRE.

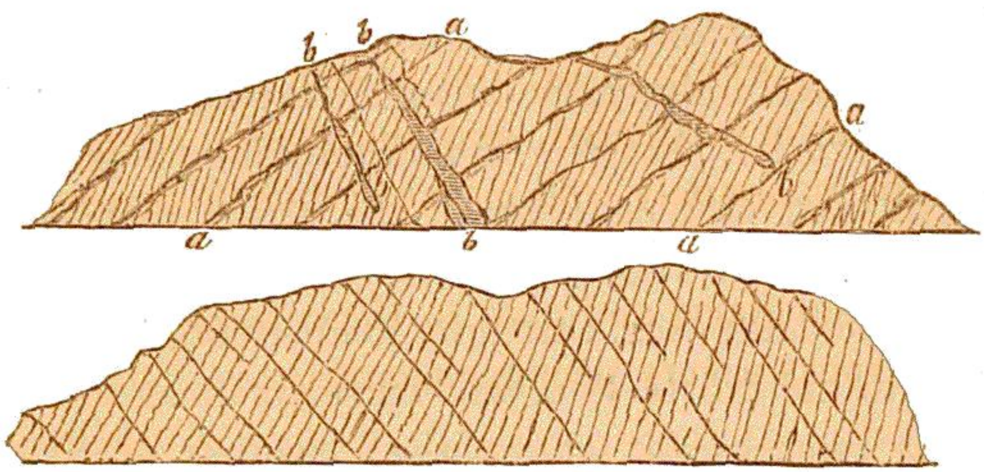
(*The lines of cleavage and stratification coincident.**)

In some instances, the lines of cleavage are in the same plane as those of the strata, as in this section (Tab. 139); 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, (Tab. 140, fig. 1), and in the slate rocks at White-

* Mr. Murchison's Silurian System, p. 399.

sand bay, in Pembrokeshire (Tab. 140, fig. 2), the discrepancy between the lines of deposition and of cleavage is strongly marked. The beds termed grauwacké, contain fragments and pebbles of clay-

1



2

TAB. 140.—SECTIONS OF CAMBRIAN ROCKS.*

Fig. 1. Section near Llandovery. Quartzose grit and sandstone; *a a* laminæ of deposit; *b b* quartz 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.

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 conglomerate, or greywacké slate. Mr. Bakewell observes, that if the red colour were absent in the conglomerates of the old red sandstone (page 613), those beds would be in every respect identical with the greywacké of these lower forma-

* Silurian System, p. 368, and p. 400.

tions. I may add, that many of the brecciated clays and shales of the Wealden, if indurated, would also closely resemble this conglomerate.

It would be a waste of time, in a popular discourse, to enter upon a minute description of the varied mineralogical characters, or of the geographical distribution, of the Cambrian strata. These beds almost universally occur on the flanks of the primary rocks; rising up into the most lofty mountain chains, and dipping beneath the newer secondary deposits. This section, by Mr. Conybeare (Pl. 10), from the Irish Sea, through Cumberland, by Durham, to the North Sea, will serve to illustrate the above remarks; it shows the elevation of Skiddaw and Saddleback, peaks 3000 feet high, by a central mass of granite; and the disruptions of the secondary strata by the intrusion of primary rocks. The relative position of the different members of the Cambrian group is seen in this section (Pl. 9, fig. 2).

Some of the slate rocks of Wales are so charged with a species of trilobite, that millions must be imbedded in those rocks:* in Normandy and Germany, similar remains are not less abundant; my collection contains specimens presented by MM. Cuvier and Brongniart. In North America, the slate system extends over immense areas; orthoceratites and spiriferæ, as in Great Britain, have been found in some of the beds.

* De la Beche.

6. Organic remains of the Silurian and Cambrian systems.—The seas, which deposited the upper division of the Silurian system, appear, as I have previously stated, to have swarmed with zoophytes, crinoidea, brachiopodous mollusca, and trilobites; of the latter, between fifty and sixty species have been discovered: some of the limestone beds and schists are almost wholly composed of their remains. The Dudley limestone, so celebrated for its fossils, is a rich storehouse of the relics of the inhabitants of the ocean which deposited the Silurian rocks. Its corals and crinoidea have been cursorily noticed in a previous lecture; they are distinct from those of the carboniferous limestone, and occur in great perfection. Its trilobites, commonly termed *Dudley locusts*, are familiar to every collector (see Tab. 131); and the chain-coral (Tab. 112), is equally well known. The remains of zoophytes analogous to the recent *sea-pen*, are figured by Mr. Murchison under the name of *graptolites*;* and impressions of some convoluted marine animal, supposed to have been a species of sea-worm (*nereis*, belonging to the *annelida*), have been found in the Cambrian rocks of Llampeter.†

Mr. Murchison observes, that no vegetables, except imperfect traces of fuci, have been observed by him or Professor Sedgwick in any of the deposits below the old red sandstone; nor any coaly matter,

* Silurian System, pl. 26. † Silurian System, pl. 27.

with the exception of small nests of culm or anthracite. From the confusion that prevailed in the classification of these rocks previously to the labours of Messrs. Sedgwick and Murchison, the foreign geological localities of organic remains referred to these formations cannot be fully relied upon. In the lower slate system, fossils are of rare occurrence; and in its few species of fuci, corals, and shells, we see the last trace of organization, and arrive at the extreme limits of the animal and vegetable kingdoms of the ancient world.

7. METAMORPHIC CHARACTER OF SLATE, AND GREYWACKÉ.—The sedimentary nature of the Silurian system, is too obvious to admit of question; layers of shells, corals, crustacea, with remains of fishes, imbedded in mud, clay, and sand, together with coarse, water-worn materials, at once evince the origin and mode of formation of these strata. 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 (page 700), but have clearly resulted from exposure to a high temperature, by which the character and arrangement of the constituent substance of the rock have been altered (Tabs. 139, 140); for a tendency to a

similar structure prevails when argillaceous beds are found in contact with lavas. It is also observed that where slate rocks have been exposed to a still greater degree of igneous action, the metamorphosis is more complete; as, for instance, when granite has been erupted in a state of fusion into fissures and veins of schist. The greywacké is evidently an indurated conglomerate, for it occurs in every intermediate state, from that of a compact rock to a loose aggregate of water-worn materials.

The numerous metalliferous veins in the slate system are either fissures into which mineral matter has sublimed, or cavities that appear to have been formed in the rock itself, and into which the metal has been introduced by segregation.

8. THE METAMORPHIC, OR PRIMARY ROCKS.—(Pl. VII. figs. 10—20; Pl. IX. fig. II.) We have at length passed the boundary which separates the animate from the inanimate world, and have entered upon those regions of geological research, in which all traces of organized beings are lost.

The primary (see pp. 16, 196,) or metamorphic rocks, so called from the supposition that they have been changed or metamorphosed by igneous agency since their original formation, are divided into two natural groups. 1st. Those rocks which, although of a crystalline structure, and destitute of organic remains, yet exhibit traces of stratification, and therefore must originally have been formed by sedimentary deposition; and 2dly, those which present no appearance of regular arrangement, but occur in amorphous or shapeless masses, or as dikes and veins filling up fissures in pre-existing rocks, or interpolated between regular strata.

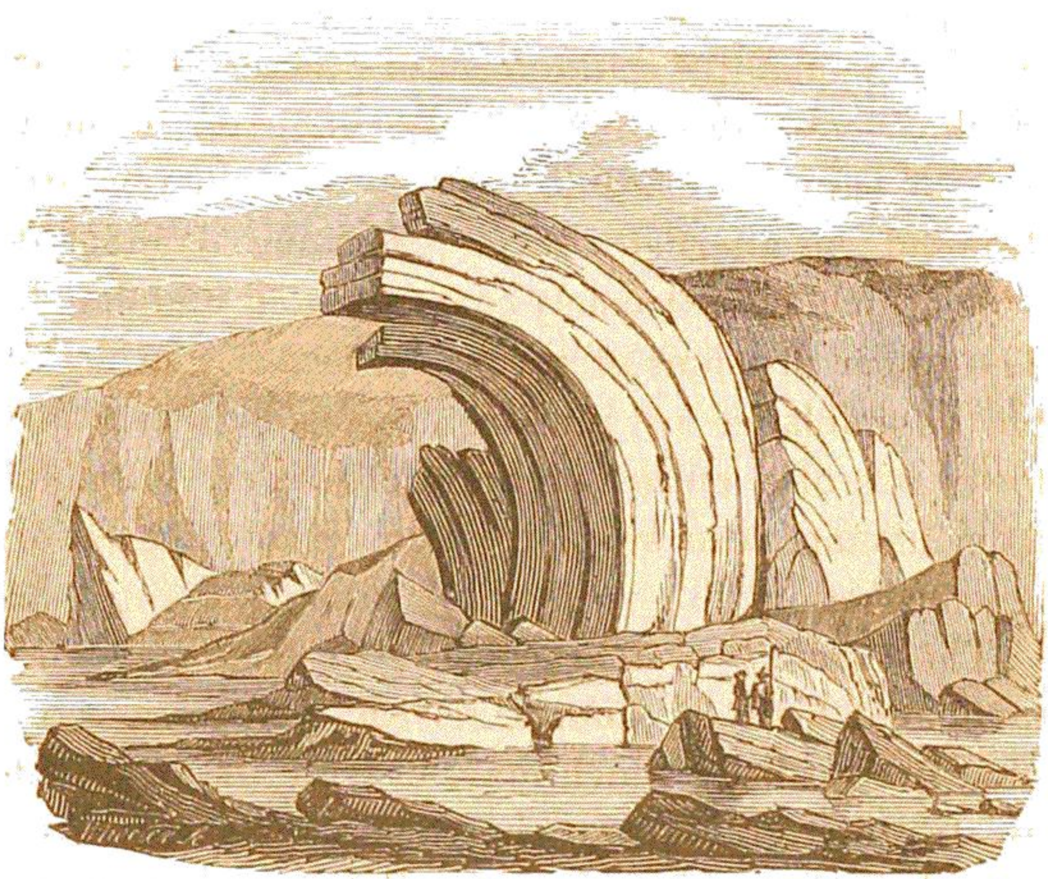
9. MICA SCHIST AND GNEISS.—The stratified metamorphic rocks consist of two well defined groups. The first, or uppermost, is *mica schist*, a slaty rock, abounding in a mineral called *mica* (from its glittering appearance), and *quartz*, a substance with which you are acquainted in the form of rock crystals, and of the semi-transparent pebbles common in most beds of shingle or beach. These two minerals are disposed in alternate layers, forming laminated beds, which are extremely contorted and undulated. The upper divisions of the series bear a considerable resemblance to the argillaceous schists; the lower are of a more quartzose character, probably from having been subjected to a greater degree of igneous action.

The *Gneiss* * system 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. The 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 con-

* A German mining term.

sidered as partaking of one 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.

The flexures and contortions in gneiss present every variety of sinuosity and curvature imaginable. The island of Lewis, in the Hebrides, so admirably



TAB. 141.—CURVED GNEISS IN THE ISLE OF LEWIS.*

(*Drawn by Miss Jane Allnutt.*)

described by Dr. MacCulloch, is remarkable for the contortions which are observable in its precipitous cliffs, and the innumerable granite veins

* Dr. MacCulloch's Western Isles, Plate 1.

with which they are traversed. The soft and ductile state in which this rock must have existed, is proved by the excessive flexures there exhibited. The face of some of the cliffs appears like veined marble paper; and the "imagination," observes Dr. MacCulloch, "can scarcely conceive an intricacy, or interlamination of this nature, of which a resemblance could not be found in 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 * (Tab. 141), which forms a highly interesting and picturesque object.

There are various substances associated with this group, as steatite, hornblende schist, chlorite schist, and the beautiful mottled magnesian rock called *serpentine;* but I must refer you to the elementary works on Geology and Mineralogy previously cited (page 186).

Mica schist and gneiss, are widely spread over and around the unstratified masses of primary rocks, of which I shall presently treat. They are scarcely known in England, but extensively prevail in the Highlands of Scotland, in the Hebrides,† and in the mountain ranges of Ireland; they also occur

* Dr. MacCulloch's Western Isles, p. 193.

† Since the admirable work of Dr. MacCulloch on the Western Isles of Scotland (1819), the Hebrides have become classical ground to the geologist.

in Skiddaw, and in Snowdon in Wales. Their geographical distribution over Europe and America is of vast extent. This system abounds in metalliferous veins. The position of the gneiss, in relation to granite, and the slate rocks, is seen in this section (Pl. IX. fig. 2).

10. UNSTRATIFIED METAMORPHIC ROCKS — GRANITE. (Pl. VII. fig. 18; Pl. IX. fig. 2; Pl. X.) —The unstratified crystalline rock, *Granite* (so named from its granular structure), constitutes the foundation upon which all the strata of which we have spoken are spread out, and the great 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 are easily recognised in the blocks of which our pavements, bridges, 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 constitute so striking a feature, as to be readily detected, even by the unscientific observer. In some granite rocks, *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*. Granite is found almost every where beneath gneiss and mica schist, and in contact with rocks of all ages, often rising into enormous masses and peaks; in the British islands it occurs in Cornwall, Dartmoor (Tab. 121), Skiddaw, and Shapfell in Cumberland, Glen Tilt, Ben Nevis, &c. It is also found in veins which traverse not only other rocks (Tab. 151), but also masses of granite, thus proving periodical formations of this crystalline rock.

In some instances, a tendency to a columnar or prismatic arrangement, is observable, and 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. An instance of the elevation of superincumbent beds of slate by granite, is seen in this section of the Cumberland rocks (Plate X); and of the carboniferous and old red strata by the granite of Dartmoor, in these sections (Tab. 121) of the formations of Devonshire. The distribution of the primary rocks in England is shown in the map (Plate X).

11. VOLCANIC AGENCY.—Throughout the vast series of stratified rocks the effect of water was every where apparent; and the existence of dry land, streams, rivers, seas, animals, and plants,

unequivocally manifest; and, although the influence of high temperature was seen in the altered character of rocks in contact with ancient lava currents, yet its effects were comparatively but feebly displayed. The metamorphic rocks, on the contrary, present unquestionable proofs of their igneous origin; and many can scarcely be distinguished from the products of modern volcanoes. To unveil the mystery in which their origin is involved, we must, consequently, as in our previous inquiry, examine those natural operations which are producing analogous results; I purpose, therefore, in this place, to review the phenomena presented by existing volcanoes.

Volcanic action is defined by Humboldt to be the influence exercised by the internal heat of a planet on its external surface, during its different states of refrigeration; by which concussions of the land, or earthquakes, and the elevation and subsidence of large portions of the solid crust, are 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 were noticed, namely, the subsidence and elevation of the Temple of Serapis (p. 94); the gradual rise of Scandinavia (p. 104); the upheaving of the sea-coast of Chili (p. 99); and other changes of a like nature. As we successively examined the tertiary and secondary formations, proofs that similar phenomena had taken place in every geological epoch, were equally manifest; the foci of volcanic action were found to have varied, but throughout the cycle of physical changes contemplated by geology, the volcano and the earthquake appeared to have been in active operation.

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 its incandescent materials have escaped. The influence of its fires on the calcareous rocks of the Apennines evolved the carbonic acid of the waters, which deposited the travertine of Pæstum, Solfatara, &c. previously described (page 60).*

12. VESUVIUS.—The celebrated mountain of Vesuvius, or Somma, is about four thousand feet high, and its summit 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 had exhibited no appearance of activity, but we then arrive at a crisis in the volcanic action of this district, which gave

* Consult Mr. Lyell's admirable description of modern volcanoes and their effects. Principles of Geology, vol. ii.

rise to "one of the most interesting events witnessed by man during the brief period throughout which he has observed the physical changes of the earth's surface."* In the year 63 A. D. 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 active. The principal eruptions are recorded in Mr. Lyell's interesting volume. I can allude but to one other remarkable event, which

* Mr. Lyell.

† Daubeny on Volcanoes, p. 152. Scrope on Volcanoes.

happened in 1538. After frequent earthquakes, a gulf opened near the town of Tripergola, which discharged mud, pumice-stones, and ashes, and threw up in the course of one day and night a mound of volcanic materials, now called *Monte Nuovo*, a mile and a half in circumference at the base, and 440 feet in height; at the same time the coast to beyond Puzzuoli was permanently elevated many feet above the level of the Mediterranean.

13. ERUPTIONS OF VESUVIUS.—In the early periods of activity, violent explosions, with showers of scoriæ, ashes, and sand, characterised 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 of fire was preceded by a bellowing of thunder in the mountain. The smaller mouth was much more 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 five or six

* The craters of Auvergne, that exhibit no traces of lava currents, are also supposed to have been produced by explosions.

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. Occasionally both burst forth at the same instant, and with the most tremendous fury; sometimes mingling their ejected stones.

"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 eighteen inches 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, which was at length lost sight of in the deep windings and ravines of the mountain."*

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. 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.

14. VOLCANIC PRODUCTS OF VESUVIUS.—The cone of Vesuvius consists of concentric coatings of

* From the Saturday Magazine.

lava, sand, and scoriæ, inclining outwards from the axis of the mountain in an angle of from 30° to 45°: a section would exhibit the structure here represented (Pl. 8, fig. 1). The fissures and rents produced in the cooled lavas and beds of volcanic products, by the earthquakes which generally precede eruptions, become filled up by subsequent ejections of melted matter, and form dikes and veins (Tab. 142); when these are injected into masses of materials which readily decompose, the solid and durable matter of the dike remains in the form of vertical walls, of which many striking examples occur in Etna, and are figured and described by Mr. Lyell.*

Lava is a term applied to any rock liquefied by heat; when consolidated by cooling, it may be in a state of scoria, pumice, basalt, obsidian, trachyte, &c. according to its mineral composition, and its slow or rapid refrigeration. 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 titani-

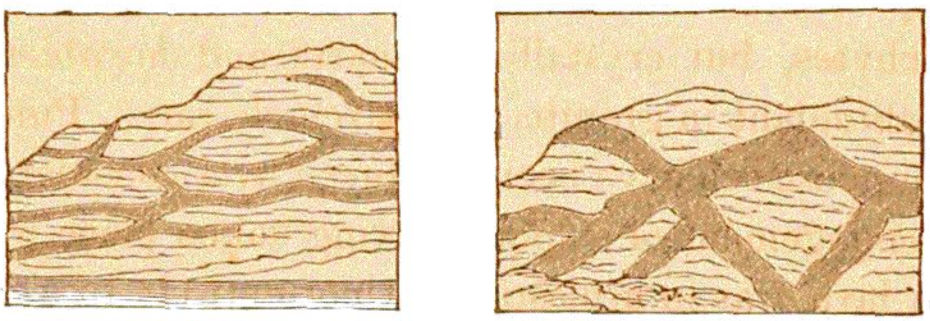
* See Principles of Geology, vol. iii. figs. 102, 105.

ferous iron constitute a large proportion of a rock, it is termed *basalt;* when the structure is slaty, it forms *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; compact heavy masses of various shades of red, yellow, brown, and grey; 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 have been 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 substance. Dolomieu observes, that some kind of pumice seems to be derived from the fusion of granite, since it contains fragments of quartz, mica, and felspar, and when such fragments were exposed to heat they were converted into a substance resembling the surrounding pumice. But I will not embarrass you by naming and describing minerals, the nature of which cannot be thoroughly understood without the patient examination of specimens. The number of simple minerals found in the rocks of Vesuvius

* Scrope on Volcanoes, p. 85.

amount to 400 species; of these my collection contains an extensive and valuable series, through the kindness of the Marquis of Northampton. In some of the ancient Vesuvian lavas, there are decided indications of a concretional and prismatic structure, and a tendency to divide into columns.

Tuff, a term which I have made use of in this discourse, designates beds composed of scoriæ, sand, and ashes, which have either been wafted by the winds, and fallen into the sea, or washed down by torrents on the plains, and agglutinated together.



1 2

TAB. 142.—DIKES AND VEINS IN LAVA.

Fig. 1. Veins or dikes of slaggy lava in volcanic tuff; Stromboli.* 2. Lava dikes in scoriæ and sand; Etna.†

Beds of tuff are often traversed by veins or dikes of slaggy lava, the product of subsequent eruptions, which have been erupted into cracks and fissures of the pre-existing volcanic mass. The conglomeration called *peperino*, and the *lapilli* or pisolitic globules of earthy matter, appear to have been fine volcanic sand, which has assumed a concretionary

* Dr. Daubeny. † Mr. Lyell.

structure. With this rapid notice of a few of the principal products of modern volcanic eruptions, I pass to the consideration of other phenomena connected with this subject.

The effects produced by lavas, and their slow or rapid progress, depend, of course, on their degree of incandescence and fluidity. 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 3200 yards. The lava 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 by fifty.* Some streams are very sluggish, and diverted from their course by any considerable obstacle; others retain a high temperature for many years. A curious circumstance occurs when trees are enveloped by lava: the upper parts and the branches alone burst out in a flame, while the trunk is only carbonized, and if subsequently removed, may leave its impression in a hollow, cylindrical tube, within the solid rock. Such moulds are common in the Isle of Bourbon, in those lava currents that have extended their ravages through forests of palms.†

15. MOUNT ETNA.—This volcanic cone, which is entirely composed of lavas, rises majestically to

* Scrope on Volcanoes, p. 92. † Ibid. p. 107.

an altitude of nearly two miles, the circumference of its base exceeding 180. 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 from fifteen to thirty miles in length, five in breadth, and from fifty to one hundred feet in thickness.* The grand feature of Etna is the *Val del Bove*, a vast plain, partially encircled by subordinate volcanic mountains, some of which are covered with forests, while others are bare and arid like those of Auvergne. This plain, which is five miles in diameter, has been repeatedly deluged by streams of lava, and presents a surface more uneven and rugged than that of the most tempestuous sea; it is inclosed on three sides by precipitous rocks, from 2000 to 3000 feet high. The face of these precipices is broken by vertical walls of lava, which stand out in relief, and are exceedingly picturesque, and of immense altitude.† The base of Etna, for an extent of twelve miles upwards, is richly cultivated, and abounds in vineyards and pastures, with towns, monasteries, and villages. The middle region is woody, being covered with forests of oak and chestnut, and a luxuriant vegetation. From about a mile below the summit, all is sterility and desolation, and the highest point is covered with eternal snow.

* Daubeny on Volcanoes.

† Lyell's Principles of Geology, vol. ii. p. 416.

The crater, from which a column of vapour constantly escapes, is about a quarter of a mile high, and three-quarters of a mile in circumference. The varied and picturesque scenery of this extraordinary mountain, the physical changes now in progress, as well as those which have taken place in periods far beyond all human history or tradition, but of which natural records still remain, are sketched by Mr. Lyell with the vigour and fidelity which characterise all the productions of his pen.*

16. PHLEGREAN FIELDS, AND THE LIPARI ISLES. —The volcanic district of Puzzuoli and Cumæ, on the bays of Baiæ and Naples, is called the Phlegrean Fields, and in it are situated Monte Nuovo, Monte Barbaro, the Solfatara, and the temple of Serapis, of which I have already spoken. 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 Solfatara constantly evolves aqueous vapour, with muriatic and sulphureous exhalations. The celebrated incrusting springs (page 60) derive their properties from the

* Principles of Geology, vol. ii. p. 415.

† Scrope on Volcanoes, p. 179.

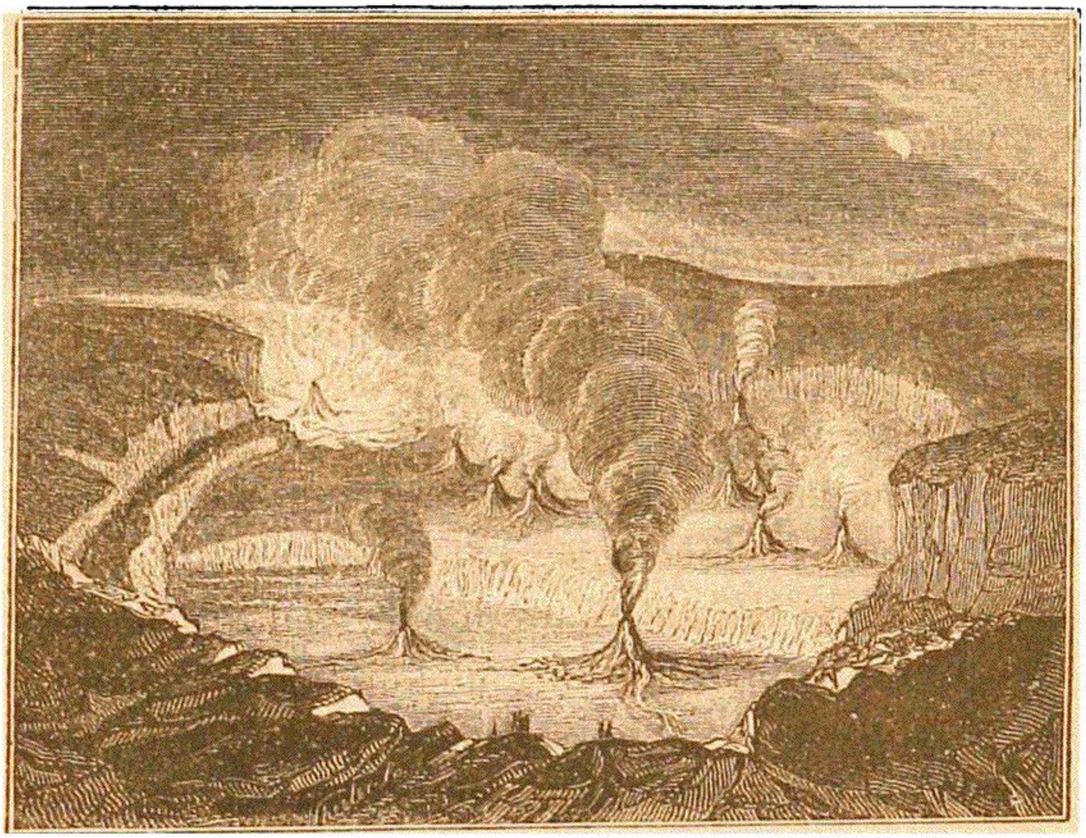
carbonic acid gas, so largely disengaged by subterranean volcanic action on limestone rocks.

The Lipari Isles, between Naples and Sicily, lying, as it were, midway between Vesuvius and Etna, present a character very analogous to the district I have just described, and their examination is replete with the highest interest. 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, which, at uncertain intervals, 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 mass then sinks down to its former level.* The interesting suite of specimens before us, were collected by William Tennant, Esq. from the cliffs of St. Calogero. These cliffs, which are about two hundred feet high, extend four or five miles along the coast, and consist of horizontal beds of volcanic tuff. From the perennial emanation of sulphureous vapour, 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, chequered, and marked with stripes of various colours. Veins of chalcedony and opal occur, and pumice-stone and obsidian are abundant. Dikes

* Spallanzani.

and veins of trachyte intersect the tuff in every direction (Tab. 142, fig. 1), and bear a striking resemblance to the intrusions of trap into the secondary strata.

17. Hawaii—volcano of Kirauea.—Of the existing volcanoes, that of Kirauea in Hawaii (for-



Tab. 143.—The volcano of Kirauea, in Hawaii.

(*From Ellis's Polynesian Researches.*)

merly called Owhyhee *), so graphically described by Mr. Stewart † and Mr. Ellis, ‡ exhibits volcanic action in its most sublime and imposing aspect. The island of Hawaii, which is about seventy miles

* One of the Sandwich Islands, well known as the scene of the murder of Capt. Cook.

† Lord Byron's Visit to Hawaii.

‡ Polynesian Researches, vol. iv.

in length, and covers an area of 4000 square miles, is a complete mass of volcanic matter, 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 account of a visit to the crater, 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 volcanic origin, the crater of Kirauea suddenly burst upon our view. We found ourselves on the edge of 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 north end of the ridge, where, the precipice 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 strata 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 connected with the action of the adjacent volcano. After walking some distance over the plain, which in several places sounded hollow under 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 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 Tab. 143). The existence of these conical craters led us to conclude, that the boiling caldron of lava did not form the focus of the volcano; that this mass of melted lava was comparatively shallow; and that the basin which contained it was 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 farther 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 craters 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 strata 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 black ledge, and had, by some subterranean canal, 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."

18. 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 subterranean 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 action 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 an ocean; billow after billow tossed its monstrous bosom in 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."

19. EARTHQUAKES.—I have indulged in these long extracts, because the vivid pictures which they present of the phenomena attendant on volcanic

action cannot fail to produce a powerful impression on the mind, and cause it to revert to those principles enunciated in the first lecture, which taught us that the early condition of the earth, and of the worlds around us, may have been one of vapour or fluidity (page 22). 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; the immense production of such gaseous elements which must be taking place in the interior of the globe, from the igneous action which we have seen 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, and elevations and dislocations of the crust of the globe, until the obstruction from the former craters is removed, or new vents are established.

20. Volcanic island in the Mediterranean.—These effects take place alike indiscriminately, either on the land or beneath the waters of the ocean. The volcanic 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. 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.*

In 1831 a volcanic island arose in the Mediterranean, about thirty miles off the S.W. coast of Sicily, where previous soundings had ascertained the depth of the sea was 600 feet. It was preceded by a fountain of steam and water, and at length a small island gradually appeared, having a crater on the summit, which ejected scoriæ, ashes, and volumes of vapour; the sea around was covered with floating cinders and dead fish. The scoriæ were of a greyish black colour, as you may observe from this

* "Nuntiatumque erat haud procul Siciliâ insulam quæ nunquam ante fuerat novam editam e mari esse."—Livy, lib. xxxix. c. 56.

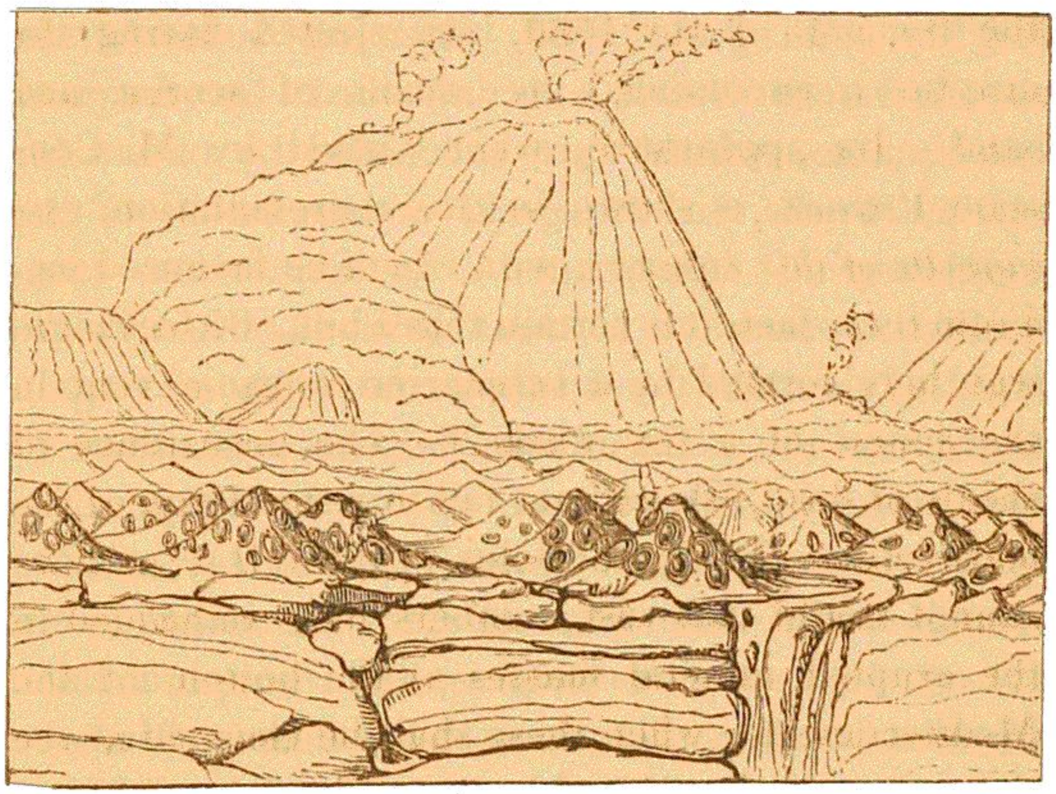
specimen.* The crater reached an elevation of nearly 200 feet, with a circumference of about three miles, having a circular basin full of boiling water of a dingy red colour. It continued in activity for three weeks, and then gradually disappeared. In 1833, two years after its destruction, a dangerous 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 Prevost, is shown in this representation, (*see vignette of this volume*), 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 (page 251): and we cannot doubt that vast numbers were imbedded in the erupted mineral masses at the bottom of the Mediterranean; when these shall be elevated above the waters, and explored by some Agassiz of future times, the then fossil fish of the Mediterranean may afford interesting subjects for the contemplation of the geologist, and the philosopher.

21. VOLCANO OF JORULLO, IN MEXICO.—(Tab. 144). Many of the lesser isles of the West Indian

* Presented by Lady Mantell; and collected from the island when it had reached its utmost extent.

† Mr. Lyell.

archipelago are of volcanic origin, and silicified corals and trunks of tropical trees occur in profusion in the alluvial debris of Antigua, and other islands. In Mexico volcanic agency has exerted itself over a great extent, and from a very early period, to the present time. In the parallel of the city of Mexico there are no less than five burning



TAB. 144.—VOLCANO OF JORULLO, MEXICO.

(*By Baron Humboldt.*)

mountains, arranged as if they originated from a fissure traversing Mexico from west to east.* But I must restrict myself to a few remarks on the modern volcano of *Jorullo;* the catastrophe

* Daubeny on Volcanos, p. 336.

attending the first appearance of this burning mountain, in the words of the illustrious Humboldt, "being one of the most extraordinary revolutions in the annals of the physical history of our planet."* An extensive cultivated plain, called the *Malpays*, covered by fields of sugar, indigo, and cotton, irrigated by streams, and bounded by basaltic mountains, constituted a district remarkable for its fertility. In June 1759, alarming subterranean sounds were heard, 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 the plain of the Malpays, from three to four miles in extent, rose up in the shape of a bladder to a height of nearly 1700 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, was thrown up, and five smaller conical mounds, and thousands of lesser cones (called by the natives *hornitos*, or ovens) issued forth from the upraised plain. These consist of clay intermingled with decomposed basalt, each cone being a *fumarole*, from which issues thick vapour (Tab. 144). The

* Nouvelle Espagne.

central cone of Jorullo is still burning, and on one side has thrown up an immense quantity of scorified and basaltic lava, containing fragments of primary rocks. Two rivers of thermal water, of the temperature of 126° of Fahrenheit, have burst through the argillaceous vault of the hornitos, and flow into the neighbouring plain.

22. Organic remains imbedded beneath lava.—In the course of these inquiries, we have been familiarized with the striking contrast presented by the effects of high temperature, exerted under great pressure, to those resulting from heat and combustion in the open air. Thus we have seen that in the earliest geological eras, eruptions of basalt have burst through and overflowed sedimentary strata, and yet the most delicate animal and vegetable substances have remained; transmuted, indeed, into stone, but still retaining their original structure —as, for instance, the vegetables of the carboniferous system, and the shells and corals of the lias, oolite, and of the chalk. In the cretaceous formation of Glaris, although the strata have been converted into slate by igneous agency, the fishes still remain (page 338)—the limestone of Monte Bolca, though capped with basalt, yet swarms with ichthyolites (page 251)—the fiery currents of Auvergne have flowed over the lacustrine limestones, and still the remains of insects, serpents, birds, and quadrupeds, are uninjured (page 260)—the tertiary forests of the Andes, which grew on beds of lava,

and now lie buried beneath volcanic masses of prodigious thickness, preserve their forms unaltered (page 276)—and the bones of the dodo are found imbedded in marlstone, covered by lava of recent origin (page 120).

23. ICE PRESERVED BY INCANDESCENT LAVA.—A circumstance of a very extraordinary nature is described by Mr. Lyell—that of the preservation for ages of a glacier, or bed of ice, from having been covered and protected by a flood of red-hot 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 consequenly felt for 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 lava current. 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 paradoxical fact, by supposing that a

* Principles of Geology, vol. ii. p. 124.

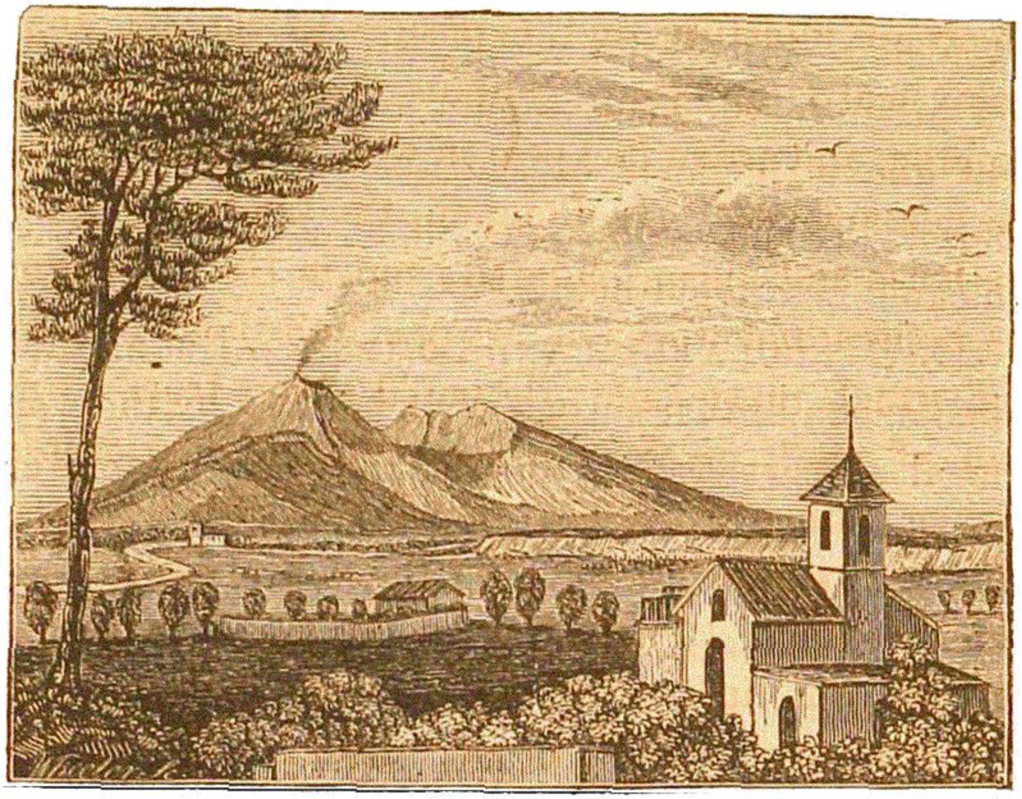
deep mass of drift snow was covered by a stream of volcanic sand, which is an extremely bad conductor of heat; and thus the subsequent liquid lava might have flowed over the whole, without affecting the ice beneath, which at such a height (ten thousand feet above the level of the sea) would endure as long as the snows of Mont Blanc, unless melted by volcanic heat from below.*

24. HERCULANEUM AND POMPEII.—But all these phenomena are far surpassed in interest by the wonderful preservation of the cities, which were overwhelmed by the first recorded eruption of Vesuvius. 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."†

* Principles of Geology, vol. ii. p. 126.

† The Last Days of Pompeii, by Sir E. L. Bulwer.

The cities of Herculaneum, Pompeii, and Stabiæ, were buried beneath an accumulation of ashes and



TAB. 145.—VIEW OF VESUVIUS, LOOKING OVER THE PLAIN AND CITY OF POMPEII.*

The site of Pompeii is marked by the long line of light in the middle distance, formed by the ashes thrown out of the excavations. The river Sarnus is seen on the left.

(Drawn by Miss Jane Allnutt.)

scoriæ, to a depth of from sixty to one hundred and twenty feet. No traces have been perceived of lava currents or of melted matter; showers of sand, cinders, and scoriæ, with loose fragments of rocks, were the agents of desolation. The various utensils and works of art, as you may observe in the lamps, vases, beads, and instruments in the British

* From Sir W. Gell's Pompeiana.

Museum, exhibit no appearance of having suffered by 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 recognisable. The remarkable preservation, for nearly 2000 years, of whole cities, with their houses, furniture, and even the most perishable substances, beneath beds of volcanic rocks, may be compared to those geological changes, by which the forests of an earlier world, and the remains of the colossal dragon-forms which inhabited the ancient land and waters, have been perpetuated.

25. Professor Silliman on geological evidence.—Although in this stage of our inquiry,

* Dr. Mac Culloch.

no farther exemplification of the nature of geological evidence is, I trust, necessary, yet I cannot deny myself the pleasure of pointing out to you the admirable manner in which Professor Silliman has illustrated the principles of geological induction, by a reference to the discovery of the buried Roman cities.

"When in 1738," he observes, "the workmen, in excavating a well, struck upon the theatre of Herculaneum, which had been buried for seventeen centuries beneath the lava of Vesuvius; when subsequently (1750) Pompeii was disencumbered of its volcanic ashes, and thus two ancient cities were brought to light; had history been as silent respecting their existence, as it was of their destruction, would not all observers say, and have not all actually said—Here are the works of man, his temples, his houses, furniture, and personal ornaments; his very wine and food; his dungeons, with the skeletons of the prisoners chained in their awful solitudes, and here and there a victim overtaken by the fiery storm? Because the soil had formed, and grass and trees had overgrown, and successive generations of men had erected their abodes over the entombed cities, and because these were covered by lava and cinders,—still does any one hesitate to admit that they were once real cities; that they stood upon what was then the surface of the country; that their streets once rang with the noise of business; their halls and theatres with the voice of pleasure; and that they were overwhelmed by the eruptions of Vesuvius, and their place blotted out from the earth and forgotten? These inferences no one can dispute—all agree in the conclusions to be drawn. When, moreover, the traveller sees the cracks in the walls of the houses of Pompeii, and observes that some of them have been thrown out of the perpendicular, and have been repaired and shored up with props, he infers that the fatal convulsion was not the first, and that these cities must have been shaken to their foundation by the effects of previous earthquakes. In like manner the geologist reasons respecting the physical changes that have taken place on the surface of our globe. The crust of the earth is full of crystals and crystallized rocks; it is replete with the entombed remains of animals and vegetables, from mosses and ferns to entire trees—from the impressions of plants to whole beds of coal. It is stored with the relics of animals, from the minutest shell-fish to the most stupendous reptiles. It is chequered with fragments, from fine sand to enormous blocks of stone. It exhibits in the materials of its solid strata every degree of attrition, from the slightest abrasion of a sharp edge or angle, to the perfect rounding which produces globular and spheroidal forms of exquisite finish. It abounds in dislocations and fractures; with injections and filling up of fissures with foreign rocky matter; with elevations and depressions of strata in every position, from the horizontal to the vertical. It is covered with the wreck and ruins of its former surface; and, finally, its ancient fires, although sometimes for a while dormant, have never been wholly extinguished, but still find an exit through volcanic mouths. When we reflect upon these phenomena, we cannot hesitate to infer that the present crust of the earth is the result of the conflicting energies of physical forces, governed by fixed laws; that its changes began from the dawn of creation, and that they will not cease till its materials and its physical laws are annihilated."*

26. BASALT, OR TRAP.—I return from this digression to the consideration of *whin*, *trap*, *basalt*, or *clinkstone;* terms which designate different varieties of an ancient volcanic rock, the nature of which I have already explained. Basalt occurs in veins or dikes, which traverse rocks of all ages, filling up fissures or crevices; and in layers spread over the surface of the strata, or interposed between them. In the diagram (Plate 7, 15), a trap-dike is represented traversing the secondary formations, and underlying the tertiary (see Plate 8, figs. vi. vii.) 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 trap or basalt, and from thence to sienite and porphyry to granite, there is an unin-

* Introduction to the third American edition of Bakewell's Geology, edited by Benjamin Silliman, LL.D., &c. 1 vol. 8vo.

terrupted succession: *as agents in geological changes trap and granite are identical.** The same eminent observer remarks, that it is a mere dispute about terms to refuse the name of submarine lavas to trap or basalt. "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 or trap, of a friable and coarse texture, are often found in the older rocks, and these Mr. Murchison has satisfactorily shown are volcanic grits, that have been formed at the bottom of the sea during the accumulation of the sedimentary matter with which they are associated. 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 interlaced with volcanic matter, that no other inference can be drawn than that the whole were of

* System of Geology, vol. ii. p. 100.

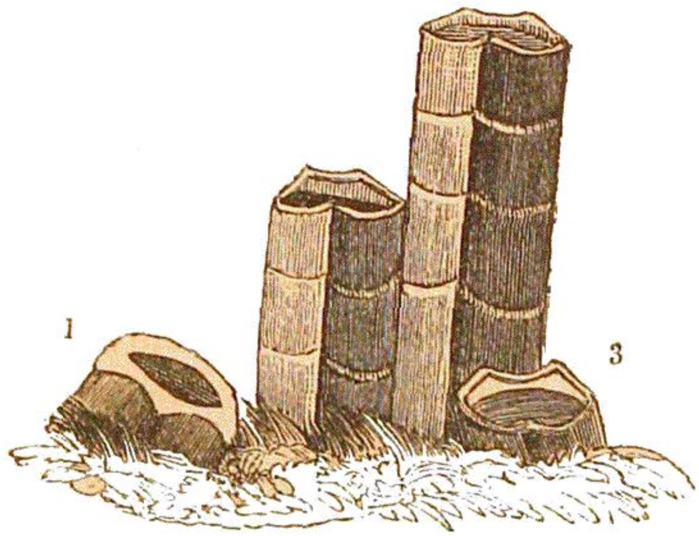
contemporaneous marine formation.* But the most remarkable form assumed by basalt, is that of regular pillars, or columns, clustered together; a character also observable in some recent lavas; the columnar basalt of the tertiary epoch has already been noticed (pages 259—268). This columnar structure is proved by some highly interesting and philosophical experiments, to have originated from the manner in which refrigeration took place. Mr. Gregory Watt † melted seven hundred weight of basalt, and kept it in the furnace several days after the fire was reduced. It fused into a dark-coloured vitreous mass, with less heat than was necessary to melt pig-iron; as refrigeration proceeded, the mass changed into a stony substance, and globules appeared; these enlarged till they pressed laterally against each other, and became converted into *polygonal prisms.* The articulated structure and regular forms of basaltic columns have, therefore, 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 been articulated together, as in these specimens of basaltic columns from the Giants' Causeway (Tab. 146).

Proofs of the correctness of this inference are

* Silurian System, p. 75.

† Philosophical Transactions, 1804.

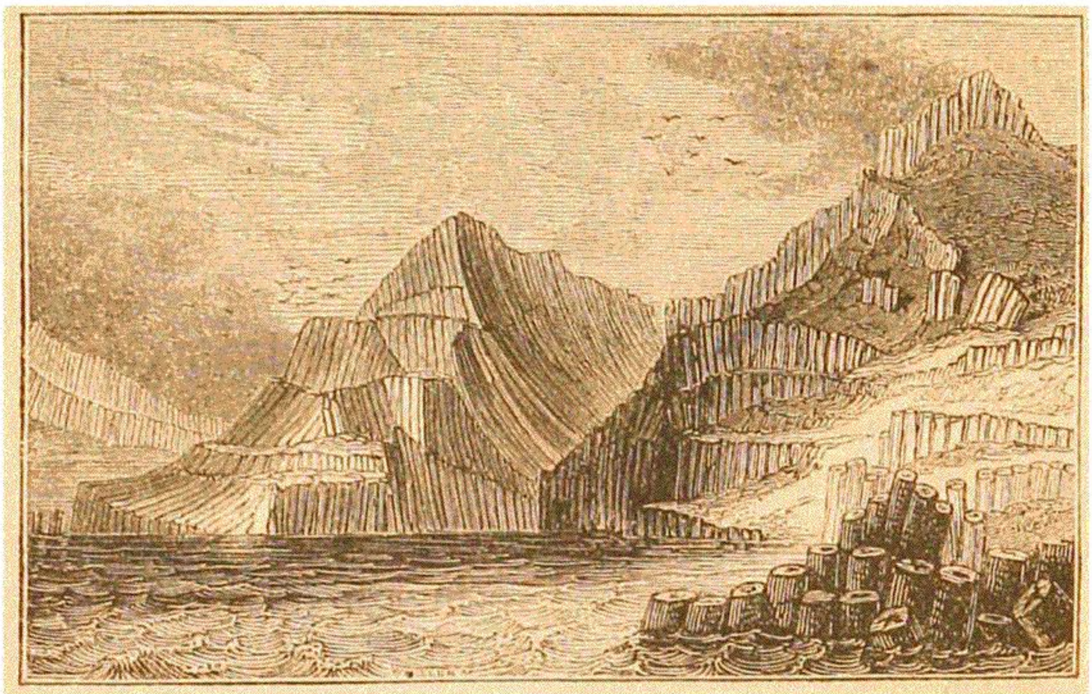
afforded by the occurrence of basaltic fragments, in which a sphere is enveloped by a polyhedral figure; and from the fact, that when basalt is not



TAB. 146.—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.

divided into regular prismatic columns, it often forms laminated spheroids, which varying in size, constitute by aggregation extensive masses of rock. 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 at Staffa and elsewhere, have originated from this cause. Before passing to the examination of the unstratified rocks, I will digress for a few moments, to direct your attention to some highly interesting examples of the columnar structure in basalt, and the changes effected on the contiguous strata, by the intrusion and contact of this ancient volcanic product.



TAB. 147.—THE ISLE OF STAFFA.

(*Drawn by Miss Duppa.*)

27. STAFFA—FINGAL'S CAVE.—Many of the Hebrides, or Western Isles of Scotland, are almost wholly composed of trap rocks. The island of Staffa* is the most celebrated, from a chasm or recess in the rock, which has been produced by the degradation and removal of the basaltic columns by the waves. This natural cavern is of singular beauty, and is well known by the English name of Fingal's Cave; but it is called by the islanders

* Staffa, a Norse term, signifying staff or column.

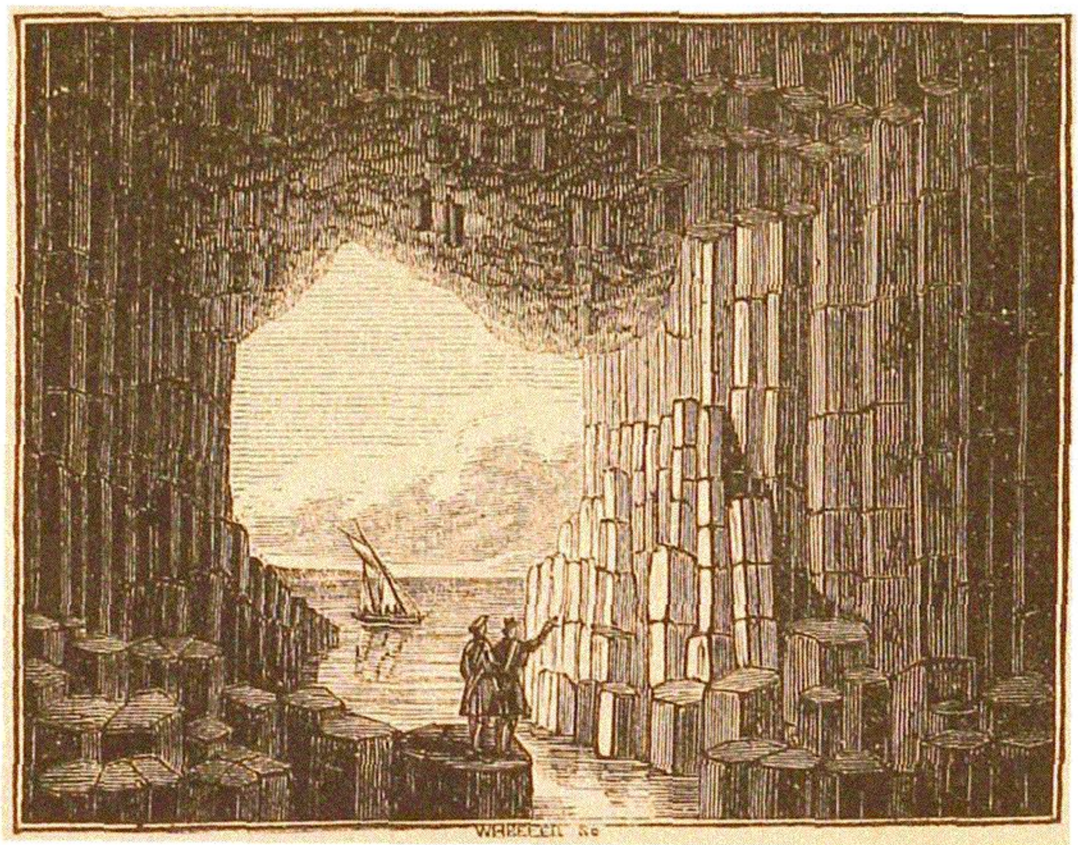
Naimh-bim, or cave of music, from the murmuring echoes occasioned by the surges, which, in rough weather, dash with violence into the chasm. To the elegant and effective pencils of Miss Duppa, and of Miss Jane Allnutt, I am indebted for the beautiful sketches of this singular cave (Tab. 148), and of the island (Tab. 147), with which these remarks are illustrated.

The Isle of Staffa is a complete mass of basalt, covered by a thin layer of soil; 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 formed 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

* Dr. MacCulloch.

diminishes to 50, and is composed of the projecting extremities of basaltic columns; the sides, of perpendicular pillars; and the base, of a causeway of the same materials. 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 marble pavement; in others, of the rough surface of the naked rock; while in many, stalactites mingle with the pillars in the recesses, and add, by the contrast of their colours,



TAB. 148.—FINGAL'S CAVE; VIEWED FROM WITHIN.

(*Drawn by Miss Jane Allnutt.*)

to the pictorial effect, which is still farther heightened by the ever varying reflected light thrown from the surface of the water, which 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 weather; but when the boisterous gales of that northern clime drive into the cavern, the agitated waves dashing and breaking among 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. But even if this cave were destitute of that order and symmetry, that richness arising from multiplicity of parts, combined with greatness of dimension and simplicity of 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.*

* MacCulloch's Western Isles.

The basalt, of which the columns are composed, is of a dark greenish-black hue, highly coloured by iron; a thin layer of silicious cement is seen 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.

28. THE GIANT'S CAUSEWAY.—In the sister kingdom, a magnificent range of basaltic pillars appears on 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. In the cliffs, a chasm, formed by the inroads of the waves, presents a natural cavern, 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 have been traversed by the basalt.

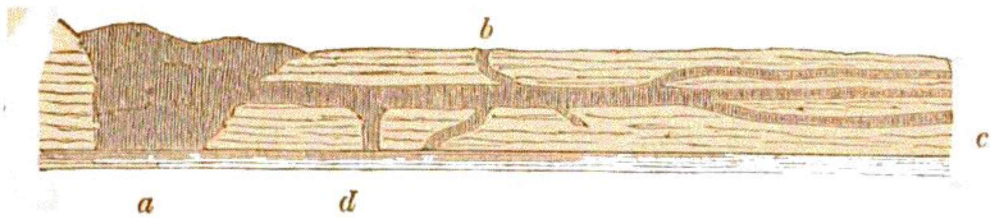
29. ROCKS ALTERED BY CONTACT WITH BASALT. —I have frequently had occasion to allude to the

changes effected in sedimentary strata by the intrusion of basalt, and other volcanic rocks (page 275); but I have reserved for the present occasion a more particular exposition of the phenomenon. The chalk in the north of Ireland, constitutes a line of cliffs traversed by basalt, which sometimes forms vertical dikes, and at others extensive beds, which have a columnar structure. The chalk is about 270 feet thick, and rests on a green sandstone, called *mullattoe*, the equivalent of the *glauconite*, or firestone (page 291); it contains flint nodules, ammonites, belemnites, echinites, terebratulæ, and the 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, Pl. VIII. fig. VI.*), which at the line of contact, and to an extent of several feet from the wall of the dike, is completely changed. Those portions of the chalk which have been exposed to the extreme influence of the lava, are now a dark brown crystalline rock, the crystals running in flakes, like those of coarse primitive limestone; the next state is saccharine—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 indurated chalk are of a yellowish, or deep-red colour; the

* Geological Transactions, vol. iii.

chalk is highly phosphorescent. The fossils are much indurated, but retain their usual structure.*

To the south of Fair Head, in the county of Antrim, syenite (page 710) traverses mica schist and chalk; and fragments of the latter are found broken up, and impacted in the erupted mass; the included portions being changed into marble. The geological relations of that part of Ireland are as follow: 1, mica slate; 2, coal shale, and new red sandstone; 3, chalk.†



TAB. 149.—TRAP DIKE ON THE COAST OF TROTTERNISH, IN THE ISLE OF SKY.‡

(*By Dr. MacCulloch.*)

30. TRAP DIKES AND VEINS.—In the Isle of Sky the intrusions of basalt or trap 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 (Tab. 149), as exhibiting vertical, oblique, and horizontal veins or

* I am indebted for specimens illustrative of these various states to G. B. Greenough, Esq., and Mr. Bryce, of Belfast.

† Mr. Griffiths. ‡ Western Isles, Pl. 17.

dikes of basalt; a large mass of trap is seen abutting endwise against the sandstone strata at *a*; from which a thick bed flows horizontally, sending off branches both upwards (*b*) and downwards (*d*), and finally dividing into three small veins (*c*). Sometimes the fracture and displacement of the strata are on so small a scale as to exhibit the relative connexion of the separated portions, as is shown in this sketch of trap intruded between sandstone, in the Isle of Arran (Tab. 151, fig. 4).

At Straithaird, in the Isle of Sky, vertical dikes and veins of trap intersect the horizontal strata of sandstone, as is shown in this sketch (Pl. 8, fig. VII.); porphyry, and other ancient lavas, also occur in the same island, in some instances protruding through, and in others spread over clay-slate, red sandstone, and shelly limestone.*

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.

31. STRATA ALTERED BY CONTACT WITH METAMORPHIC ROCKS.—From this subject I pass to the consideration of the changes produced by granite, and other ancient metamorphic mineral masses. The transition from granite to modern porphyritic trachytes, passes through infinite gradations, but

* Dr. MacCulloch.

all the modifications appear 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 examples of this transmutation occur. In some instances the beds in contact with the fundamental rock of schist, are irregular and perfectly crystalline, but change to a stratified disposition, and earthy texture, in proportion as they are further removed from the

* Edinburgh Journal of Science.

schist. In other instances, the metamorphosis takes place more gradually, each bed of limestone (*a*) losing its stratified character, and becoming irregular and crystalline (*b*) when it is in contact with the schist (*c*), as is shown in this sketch (Tab. 150);

TAB. 150.—CHANGE OF STRATIFIED INTO CRYSTALLINE 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.

32. GRANITE VEINS.—Veins, I have previously stated (page 192), are fissures or chasms, origi-

* Western Isles of Scotland, Pl. 27.

nating either in mechanical disturbance, or from contraction in mineral masses during their consolidation; and these veins are generally found filled by subsequent segregation, or infiltration. It is obvious that all veins must be of later origin than the rock which they traverse. Thus the veins of granite, represented in this diagram, (Tab. 151, fig. 1), are more modern than the mass through which they are disseminated. It therefore follows that when rocks of granite are intersected by veins or dikes of the same substance, the latter are of later origin than the former, and have been injected into rents and openings of pre-existing granite rocks; a proof that the formation of granite has taken place at more than one epoch.

The mode in which slate is intersected by granite veins is well shown in this representation (Tab. 151, fig. 1). Granite veins traversing other rocks are themselves sometimes intersected by intrusions of other melted materials. This sketch (Tab. 151, fig. 2) represents a mass of schistose rock, which is intersected by granite veins (*a a*) in one direction, and is again traversed by veins of porphyry (*b b*), which cut through both the schist and the granite. When gneiss is intersected by granite, it becomes shifted, as in this representation (Tab. 151, fig. 3), where the granite veins (*a a a*) have displaced the laminæ of gneiss (*b b*). By numerous observations of phenomena of a like nature, it is now clearly established that granite has been ejected during the

Cambrian, Silurian, carboniferous, oolitic, cretaceous (see Pl. 8, fig. VII.), and even tertiary epochs.

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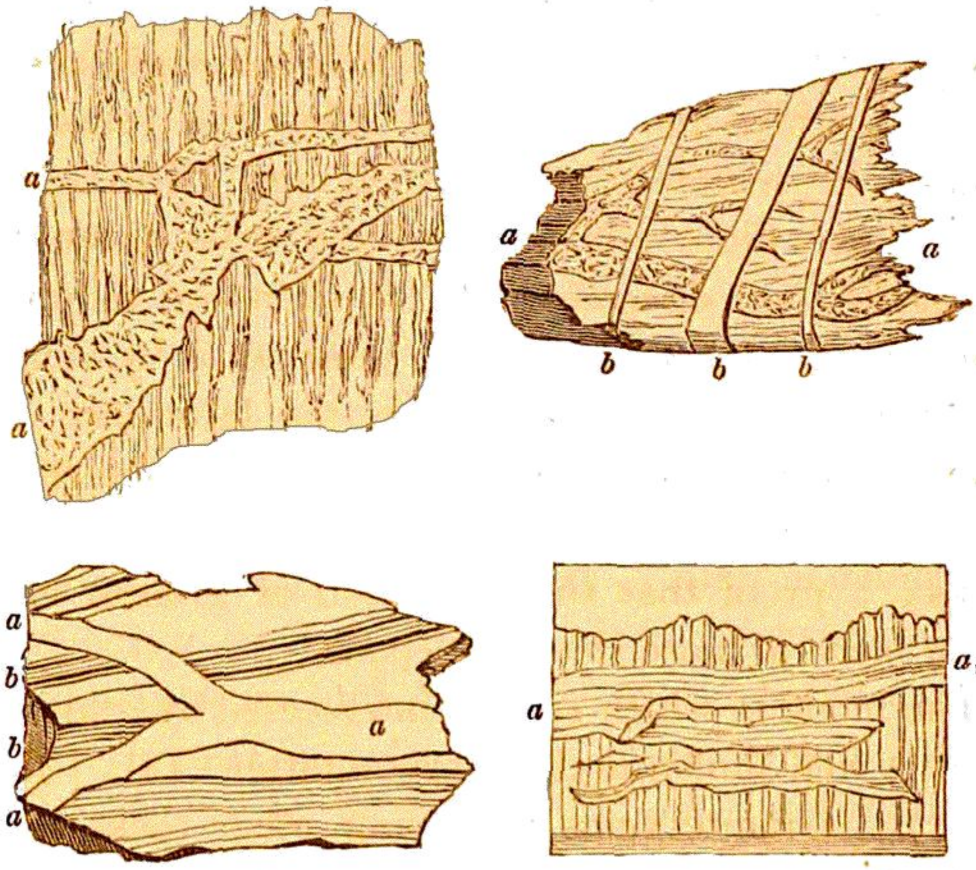

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TAB. 151.—INTRUSIONS OF TRAP, GRANITE, PORPHYRY, &c. ISLE OF ARRAN.

Fig. 1. Granite veins (*a a*) traversing schist.* 2. Veins of granite (*a a*), traversing schist, themselves crossed by veins (dikes) of two different kinds of porphyry (*b b b*). 3. Gneiss, 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.†

Where granite has been erupted among the secondary strata, the latter, as we have already remarked, are

* Phillips, Encycl. Metrop.

† Dr. MacCulloch, Geolog. Trans. and Western Isles.

invariably altered near the line of junction; but when consolidated masses of granite have been protruded, no such change is observable. Into the slate rocks of the Cambrian chain, sienite, 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. In the Isle of Arran, and other places, the granitic rocks were evidently erupted in a state of fusion, for the slates are penetrated by veins of granite (Tab. 151, 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. An extraordinary fact is noticed by M. Elie de Beaumont. In the environs of Champoleon, where granite comes in contact with the 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 harder and crystalline, while the granite has undergone a contrary change.* Mr. Lyell describes a remarkable example of the change induced in stratified rocks by intrusions of sienite

* De la Beche.

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.

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, which is the 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 *rocking-stones*, and the *cheese-wring* of Cornwall, are examples.*

33. METAMORPHOSED ROCKS. — Enough has been advanced to convey a general idea of the character and relation of the primary crystalline rocks, and of the agency which has reduced them to their present state; but the question naturally arises—what was their original nature? *Intense* heat has effected the present arrangement of their molecules, but upon what materials was that influence exerted? *The transmutation*, by heat, 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

* Dr. MacCulloch, System of Geology.

—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 theory of an eminent geologist and chemist, M. Fournet, *that all the primary rocks are simply sedimentary deposits metamorphosed by igneous action ;** this opinion, however, is but a modification of that long since expressed by our illustrious countryman, Hutton, that granitic rocks are consolidated and altered sediments which were originally accumulated at the bottom of the sea.

34. METALLIFEROUS VEINS.—In my description of the fissures observable in consolidated strata, I mentioned that the great depositaries of the metals are found 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 of formation, nor to any tracts of country, although most frequent in beds that form mountain elevations, and in the oldest rocks. I have already mentioned (page 276), that veins of iron, copper, arsenic, silver, and gold, occur in

* The general reader will find an interesting account of M. Fournet's theory in Jameson's Edinburgh Journal, No. xlvii. p. 3.

tertiary strata. Veins are evidently fissures of mechanical origin; they have been opened by elevatory forces, and in some instances have been filled from beneath by the sublimation of metalliferous matter by igneous action; and in others, from the surface, by the transportation of various materials which have flowed into them. In other examples the veins are connected by a gradual mineral transition with the contiguous rocks, and then appear to have resulted from an electro-chemical "separation, or segregation, of certain mineral and metallic particles from the mass of enveloping rock, while it was in a soft or fluid state, and their determination to particular centres." The nature of these veins receives illustration from those nests of spar and mineral matter in masses of trap rocks, from Scotland, 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 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 great weight to the hypothesis which refers the filling up of some veins to electrical agency. M. Becquerel remarks, that when a vein is filled either

* Mr. Lyell's Anniversary Address.

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.*

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 is a brief notice of the geological distribution of a few of the chief metals.

Lead.—The ores of this metal are very numerous: and the sulphuret, or galena, occurs in primary and secondary rocks.

Tin—exists in veins traversing granite and schist; those of Cornwall have been celebrated from the earliest historical period.

Copper—is found in primary and secondary rocks, and is often *native*, that is, in a pure metallic state; and crystallized.

Gold—exists in granite and quartz rocks. The gold found in the mud and sands of rivers (as these grains from Ovoca in Ireland, collected by the late Earl of Chichester,) is derived from disintegrated rocks.

Silver.—This metal is found in transition and primary rocks; sometimes native (as in these specimens from Cornwall, from the mines of my friend, John Hawkins, Esq. of Bignor Park); and in ores associated with arsenic, cobalt, &c.

The almost universal presence of the ores of iron, and the infinite variety of its combinations, are well known. The formation of what is termed bog-iron

* Mining Journal, vol. iv. p. 71.

† Mr. Burr. ‡ Professor Phillips.

ore, found in marshes and peat-bogs, is supposed to have been derived from the decomposition of rocks over which water has flowed; but the observations of Ehrenberg, to which I shall presently advert, seem to indicate a different origin.

35. COPPER ORE OF NEW BRUNSWICK.*—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 the metallic ores are usually blended with their accompanying veinstones. This bed bears a close analogy to the modern cupreous deposits of Anglesea, or 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 would appear 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,

* Mining Review, vol. iv. No. 4. By Frederick Burr, Esq.

and formed the singular compound deposit under consideration, over which, probably at a subsequent period, the alluvial covering was drifted.

36. THE SAPPHIRE, RUBY, AND EMERALD.—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 oriental ruby, 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 two former consist principally of aluminous earth;* and the supposition that they have been formed by intense igneous action, is not only probable, but is rendered almost certain, by the late experiments of M. Gaudin, who has succeeded in producing fictitious rubies, which, in every respect, resemble the natural gems. These were formed by submitting aluminum, 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. Instances occur in which garnets and other crystals are found in shale, when altered by

* The sapphire affords, by analysis, 98·5 of alumine, 0·5 of lime, and 1 of oxide of iron; the ruby, 90 of alumine, 7 of silex, and 1·2 of oxide of iron.—*Phillips's Mineralogy.*

contact with a dike of granite or trap, though altogether wanting in every other part of the rock; a proof that they have been produced by the effects of heat on those parts of the sedimentary deposits which were most exposed to the influence of the erupted mass.*

37. Review of the Silurian and Cambrian systems.—Let us now review the leading phenomena which have been brought under our notice in this discourse. The Silurian system presented all the usual characters of sedimentary deposits, with which our previous investigations have rendered us familiar. Its marine origin is evinced by the organic remains; and the strata have evidently been formed and consolidated by mechanical and chemical agency, acting through a long period of time, in like manner as in the production of the newer secondary formations. The fossils consist of a few algæ, equiseta, lycopodiaceæ, and ferns; about ninety species of polyparia, of which the lamellar and cellular corals form by far the largest proportions; thirty-five species of crinoidea; about two hundred and sixty species of bivalve shells, and eighty of cephalopoda; sixty-five species of trilobites, or other crustacea; and the remains of a few species of fishes. Mr. Murchison, from his extensive collection of fossils, has selected several which he considers characteristic of the four groups into which he has subdivided the system; and these

* Mr. Lyell.

fossils, with but few exceptions, are specifically distinct from those of the Devonian system; and not one of them have been found in the carboniferous strata.*

In the Cambrian, or slate 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. About twenty or thirty species of shells and corals, consisting of cyathophylla, spiriferæ, productæ, &c. are the only organic remains: and as these occur in the upper part of the system, it may probably hereafter be found convenient to separate the Silurian from the Cambrian, at a lower level, and thus include the fossiliferous strata in the former grand division. In accordance with the slaty structure, is the prevalence of melted rocks throughout the Cambrian epoch; for not only do granite, porphyry, serpentine, and trap, occur in veins and dikes, but also intercalated with the strata, as if the melted matter had been poured over argillaceous sediments at the bottom of the sea, and had become covered by succeeding deposits.

* See Silurian System, p. 585. Mr. Murchison evidently anticipated that the old red system would be characterised by its peculiar organic remains.

These two systems, therefore, afford incontrovertible evidence of marine depositions going on through an immense period of time, during which the sea abounded in polyparia, mollusca, and crustacea; for although organic remains prevail only in the uppermost or newest group, yet as we have decided proof that the lowermost division has been subjected to intense heat, and that even the lines of stratification are in a great measure melted away, it is clearly reasonable to conclude, that the absence of fossils may be attributable to the obliteration of the remains of the animals which lived and died in the waters that deposited the slate. We must not, however, fail to remark, that the relics of organized beings which remain are of a peculiar type, and altogether different from the corals and shells of the newer secondary formations.

38. Review of the metamorphic rocks.—The traces of stratification, a structure which, we have seen, is characteristic of aqueous formations (page 189), are evident in the upper group of the crystalline metamorphic rocks; and there is also an obscure resemblance 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 wanting; and in the amorphous masses, veins, and dikes, we see the effects of long continued and intense igneous action, produced under

circumstances which have given to the resulting rocks a very peculiar character. 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, namely, 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 into the hardest and purest crystal, was shown in the formation of fictitious rubies (page 764). 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 phenomena into consideration, together with the facts previously stated, of the transmutation of one substance into another by heat, it appears to me, that in the present state of our knowledge, we are warranted in concluding that granite and its associated rocks, are nothing more than sedimentary deposits altered by igneous agency. But from what source were the most ancient granite rocks derived—whence originated

* Jameson's Edinburgh Journal, No. 47.

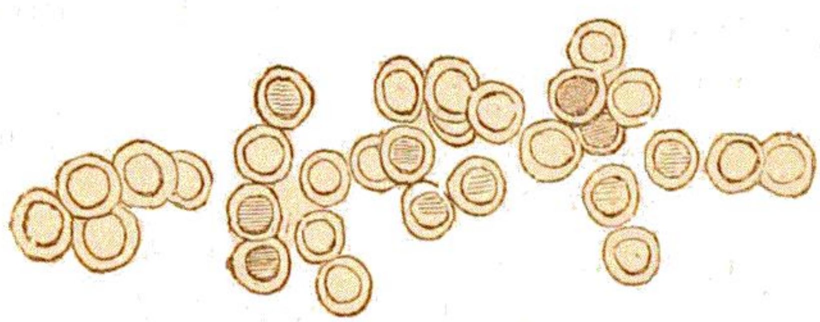
the materials upon which igneous action exerted its influence, and produced those crystalline masses which are the *ultima Thule* of geological research? These are questions which in the present state of our knowledge we are not in a condition to solve.

39. Organic remains in the metamorphic rocks??—I have before stated, that with the last or lowermost of the slate rocks, all traces of organization are lost; but this assertion requires some modification, 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 now resume the inquiry. From the intense heat to which the metamorphic rocks have been exposed, we cannot expect to find any elementary organic structures, except those which are formed of materials capable of resisting the effects of such an influence. The observations and experiments of Mr. Reade have shown (page 647), that vegetables possess a structure which is composed of silex, and is indestructible in a common fire. In animals, we seek in vain for an elementary tissue, capable of resisting the powerful influence of heat, except in those minute beings, the infusoria, of which I treated in a previous lecture (pages 324, 567). The silicious skeletons and shields of the infusoria, are, indeed, the only animal structures that can escape

* Western Isles, p. 514.

destruction, in substances subjected to the influence of a high temperature; and it is clear, that if the skeletons or durable parts of any other animals were exposed to such an agency, all traces of their organization would be obliterated. It would therefore be a hopeless task to seek for any indications of animals, except of those which, like the infusoria, possessed silicious skeletons, in rocks where even the lines of stratification are melted away. When speaking of the fossils of the chalk, it was stated that the coatings of many of the flints contained myriads of the silicious skeletons of animalcules, and that some rocks are almost wholly composed of such remains (page 324).

Ehrenberg, to whom we are largely indebted for opening this new field of inquiry, has discovered the remains of this class of animals in numerous deposits. Thus the ferruginous or ochreous film or scum seen on the water of marshes, or 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 infusoria *(gaillonella ferruginea)*. 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 infusoria *(naviculæ)*. The semi-opal, and the tripoli of the tertiary deposits, are wholly composed of the fossil remains of this class of animals. In the secondary formations, we have seen that they are equally abundant.* Ehrenberg also 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 formation 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.



TAB. 152.—FLAT CIRCULAR BODIES IN MICA SCHIST.

Corresponding in size and appearance with the rings of gaillonella distans; magnified about 500 times linear.

(By Rev. J. B. Reade.)

I will now place before you Mr. Reade's remarks and drawings of the apparently organic bodies in mica schist (Tab. 152), and which, from their

* See Appendix N. & O.

peculiar action upon light, are supposed to be silicious.* At present, my information on this highly interesting inquiry extends no farther.

40. RELATIVE AGE OF MOUNTAINS.—We have seen that the intrusions of melted rocks, have not only altered the chemical nature of the strata through which they were erupted, but have also changed their position and relations, and produced corresponding modifications in the physical geography of the dry land, transforming plains into mountain peaks, and occasioning the subsidence of elevated regions to the bottom of the deep. As these revolutions 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

* These are inserted in the Appendix N. I would refer the reader, whose curiosity is awakened by these remarks, to the Third Part of Mr. Taylor's scientific Memoirs, for a translation of two of Ehrenberg's Memoirs on Fossil Infusoria. London, 1807, price 6*s*.

of the results which have been obtained. The positions and relations of the secondary strata afford the principal data by which this problem may be solved; for, as 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 deposited, 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, it is evident that the mountains must have been elevated before the formation of the surrounding deposits. It is by cautious inductions of this kind, that a distinguished savant, M. Elie de Beaumont has shown—1. That the mountains of Erzegebirge, in Saxony, and of the Côte d'Or in Burgundy, are newer than the Jura limestone, but older than the green sand 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 newer 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 Sedgwick.

That the *sudden* protrusion of such immense masses as the Alps or Pyrenees from the bottom of the sea, must have dislodged a vast body 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, no such effects would have been produced.

41. SUCCESSION OF CHANGES IN THE ORGANIC KINGDOM.—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 fully comprehend, and retain a clear conception, of the leading principles and inferences of geology. To condense my remarks as much as possible, I purpose offering—*firstly*, a summary of the changes which have taken place in the animal and vegetable kingdoms; and, *secondly*, in the physical conditions of the earth's surface, during the vast periods which our investigations have embraced; and, *thirdly*, a review of the influence exerted by vital action in the elaboration of the solid materials of the globe. I shall conclude by a few general observations on the highly important and interesting facts, that have formed the subject of our contemplations.

So numerous and varied have been the phenomena examined, that in order to recall the principal events which have marked our progress, I place before you the series of illustrations employed in these lectures, that you may perceive at a glance the striking contrast presented by the fauna and flora of different geological epochs.* In the first stage, traces of the existing orders of animated nature were everywhere apparent; and works of art, with the bones of man and the remains of vegetables and of animals, were found in the modern deposits. In the succeeding era, many species and genera, both 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, crustacea, and mollusca, as at the present time.

The next epoch presented one wide waste of waters, teeming with the general types of marine beings, but of different species and genera to those of the previous eras, and bearing a large proportion of cephalopodous mollusca. A few algæ and fuci made up the marine flora; and drifted trunks of coniferæ and dicotyledonous trees, with a few reptiles, were the only indications of the dry land and its inhabitants. The delta of a mighty river now appeared, containing the spoils of an extensive island

* The reader may realize this idea by referring to the illustrations of these volumes, commencing with the fossil human skeleton (p. 75), and proceeding from the large mammalia (pp. 141, 162, 241), to the last of the series, the corals, shells, and plants, of the ancient secondary deposits (pp. 571, 588, 682, &c.)

or continent; and the remains of colossal reptiles, and of unknown forms of tropical plants, marked the era of the country of the iguanodon.

We were then conducted to other seas, 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. In the next era, we found another sea swarming with fishes, mollusca, and corals, and with reptiles similar to those of the preceding period.

The succeeding change disclosed extensive regions, covered by a luxuriant vegetation; 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 character wholly unknown in modern floras. The ocean abounded in mollusca, radiaria, and crustacea, of genera and species, unlike any that had previously appeared.

We advanced to other oceans, swarming with polyparia, mollusca, radiaria, and fishes, which bore some analogy to those of the preceding seas, but belonged to different species: interspersions of cryptogamous plants, with a flora related to the one immediately antecedent, marked the existence of dry land. But 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 indications of infusoria were the last vestiges of organic life.

42. SUCCESSIVE DEVELOPMENT OF THE ORGANIC KINGDOMS.—If we reverse the order of the argument, and pass in succession from the ancient to the modern epoch—from the regions of sterility and desolation, 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.
Granite	*Infusoria??*	No traces of vegetables.
Lower slate system	*Corals* and *shells* (*brachiopoda*)	Fuci?
Upper slate system	*Corals*, *crinoidea*, shells, and *trilobites*	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???*	Several hundred species of plants; the *vascular cryptogamia* largely developed. Palms, tree-ferns, coniferæ. Dicotyledonous plants very rare.
Upper secondary	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 *marsupial mammalia—Didelphis;* and one of *birds—Ardea*	*Zamiæ*, *Liliaceæ*. Palms. Tree ferns. Coniferæ. 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	Remains of the existing vegetation.

This rapid sketch, presents but an outline of the most striking changes observable in the organic forms, preserved in the several formations of the sedimentary deposits. 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 larger development 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 life, particularly of the cryptogamic class. Large reptiles next prevail to an extraordinary degree; and one genus of birds, and two genera of mammalia, attest the existence of the higher orders of animals. The vegetable kingdom is greatly modified; and plants related to the zamiæ and to the liliaceæ preponderate, with coniferæ and dicotyledonous trees. The next remarkable change is in the sudden increase of mammiferous animals, and the reduction of the reptile tribes; the large pachydermata, as the mammoth, elephant, &c. first appear. From this period till the creation of man, there are no striking general modifications in the various orders of animal and vegetable existence.

It was from this *apparent* 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

* See Organic Remains of a Former World, vol. iii. p. 449.

need remark, that the facts we have stated warrant no such inference: we have seen that the minutest living atom possesses a structure as wonderful as our own; and that some of the fossil animals which first appear in the strata, belong to families with a highly developed organization. Nor does the vegetation of the earliest periods lend any support to such a hypothesis; fungi, lichens, hepaticæ, or mosses, as I have before remarked, do not form the flora of the carboniferous strata, but coniferæ, and the most perfectly organized of the cryptogamic class.

43. GEOLOGICAL EFFECTS OF MECHANICAL AND CHEMICAL ACTION.—The physical changes that have taken place in the earth's surface, are in perfect harmony with the modifications observable in animated nature; for the laws of mechanical and chemical action are indissolubly connected with those which govern vital phenomena; and we have incontrovertible evidence, that throughout the vast periods over which geological speculations extend, the same causes have operated, the same effects followed. Thus, heat and cold, drought and moisture, and other atmospheric influences, have dissolved the loftiest peaks—rivulets and torrents have eroded the sides of the mountain-chains—streams and rivers have worn away the plains, and carried 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—limestones into marble—clay into slate, and sedimentary into crystalline masses; 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 both fire and water have been constantly exerted; the phases of action have alone differed in duration and intensity.

44. ROCKS COMPOSED OF ORGANIC REMAINS.—In a previous discourse I dwelt upon the highly interesting subject of the elaboration of solid material from gaseous and fluid elements by vital action, and the formation of islands and continents by countless myriads of living instruments. It is my present purpose to consider how far the present solid materials of the earth's surface have been derived from organized beings. The processes by which animal and vegetable structures are converted

into stone, and the various states in which their fossil remains occur, have already been explained.

The strata of vegetable origin consist of peat—of forests ingulfed by subsidences of the land, or imbedded in the mud of rivers and deltas, or in the basin of the sea—of the lignite and brown coal of the tertiary deposits—of the coal and shales of the carboniferous strata—and of the silicified and calcareous trunks of trees in tertiary and secondary formations. But the deposits which are derived either wholly or in part from animal exuviæ are so numerous, and of such prodigious extent, that the interrogation of the poet may be repeated by the philosopher—

"Where is the dust that has not been alive?"—YOUNG.

Probably there is not an atom of the crust of the globe, which has not passed through the complex and wonderful laboratory of life. Thus we find that all the orders of animals, from the infusoria up to man, have more or less contributed, by their organic remains, to swell the amount of the solid materials of the earth. The following tabular arrangement presents in a condensed form some of the most striking results.

ROCKS COMPOSED WHOLLY OR IN PART OF ANIMAL REMAINS.

Strata.	Prevailing Remains.	Formations.
Trilobite-schist............	Trilobites	Silurian system
Dudley limestone	Corals, crinoidea, trilobites and shells	—

Strata.	Prevailing Remains.	Formations.
Shelly limestone	Productæ, spiriferæ, &c.	Silurian system
Mountain limestone ...	Corals and shells......................	Carboniferous system
Encrinital marble	Lily-shaped animals and shells	—
Muscle-band..............	Fresh-water muscles	—
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, fish, insects... ...	—
Bath-stone................	Shells, corals, crinoidea, reptiles, fishes	—
Ammonite limestone ...	Cephalopoda, principally ammonites	—
Coral-rag	Corals, shells, *echini*, ammonites...	—
Bradford limestone......	Crinoidea, shells, corals, cephalopoda	—
Portland *oolite*...........	*Ammonites, trigoniæ, and other shells*	—
Purbeck and Sussex marble	Fresh-water shells, crustacea, reptiles, fishes	Wealden
Wealden limestone	Cyclades, and other fresh-water shells, crustacea, reptiles, fishes...	—
Tilgate grit (some beds)	Reptiles, fishes, fresh-water shells ...	—
Faringdon gravel	Sponges, corals, echini, and shells ...	Shanklin sand
Jasper and chert	Shells	—
Green sand	Fibrous zoophytes	—
Chalk	Corals, radiaria, echini, shells, fishes	Chalk
Maestricht limestone ...	Corals, shells, ammonites, belemnites, and other cephalopoda—reptiles ...	—
Hippurite limestone ...	Shells, principally hippurites	—
Hard chalk (some beds)	Echini and belemnites	—
Flints	*Sponges, and other fibrous zoophytes*	—
	Infusoria, and spines of zoophytes ...	—
	Echini, *shells*, corals, crinoidea	—
Limestone	Fresh-water shells	Tertiary
Nummulite rock	Nummulites...............................	—
Septaria	Nautili, turritellæ, and other shells	—
Calcaire grossier	Shells and corals	—
Gypseous limestone......	Mammalia, (palaotheria, &c.) birds, reptiles, fishes	—
Silicious limestone	Shells	—

Strata.	Prevailing Remains.	Formations.
Lacustrine marl	Cyprides, phryganeæ, fresh-water shells	Tertiary
Monte Bolca limestone	Fishes...	—
Bone-breccia..............	Mammalia, and land-shells	—
Sub-Himalaya sandstone	Elephant, Mastodon, &c. reptiles ...	—
Tripoli	Infusoria	—
Semiopal	Infusoria	—
Guadaloupe limestone .	MAN, land-shells and corals...........	Human epoch
Bermuda limestone......	Corals, shells, serpulæ	—
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, &c. first appearing in the most recent accumulations; and by the geological causes now in action, not only the remains of the existing orders of living beings, but also works of human art, are added day by day to the solid crust of the globe.

45. 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 nevertheless venture to draw some general inferences as to the varying physical conditions of our planet, and of animal and vegetable life, through the immense periods contemplated by geology.

From the remotest epoch in the earth's physical history recognizable by man, to the present time, the mechanical and chemical laws, which govern inorganic matter, appear to have undergone no change. The wasting away of the solid rocks by water, and the subsequent deposition, and consolidation of the detritus by heat; the subsidence of the dry land beneath the sea, and the elevation of the ocean-bed into 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 constantly been 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 in perfect harmony with those which regulate inorganic matter. Every creature was especially adapted to some peculiar state of the earth at the period of its development; and when the physical conditions were changed, and no longer favourable for the existence of such a type of organization, it necessarily became extinct.* Thus we have seen different modifications of animal and vegetable life prevailing at different epochs of the earth's physical history, yet all presenting the same principles of structure, the same unity of purpose; all bearing the impress of the same Almighty hand. The creation of man, and the establishment of the existing 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 philosophy.

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 periods to the present time; and that the absence of the fossil remains of whole orders of animals in the remotest periods, although, perhaps, in some measure attributable to the feeble development of those types of being, may have been also dependent on the obliteration of their remains in the igneous rocks by high temperature: at the same time we must not forget, that we are examining ancient ocean beds, and may not yet have explored those parts of their vast abysses in which the spoils of the land are concealed. I need not add, that the assumption of successive creations of new forms of being,

* See page 115.

adapted to the varying physical conditions of the earth, is only modified, not weakened, by this argument.

What, then, is the result of our inquiry into the ancient state of our globe?—That, so far as our present knowledge extends, all the changes produced by mechanical, chemical, or vital agency, whether on the surface or in the interior of the earth, have been taking place from the earliest periods revealed by geological research; and, as like causes must produce like effects, will continue to take place so long as the present material system shall endure. Thus deposits now in progress may subside to the inner regions of the earth, and by exposure to long continued igneous action, all traces of sedimentary origin may be destroyed; and at some distant period, the metamorphosed masses may appear on the surface in the form of peaks of granite, bearing with them the accumulated spoils of numberless ages. I cannot, therefore, concur in the opinion of those, who imagine that in the granite we see the primeval solid framework of the globe—a consolidated crust formed on the surface of a cooling planet, and subsequently broken up by changes in the temperature of the earth. To me it appears that the only legitimate inference in the present state of our knowledge, is that the solid materials of our globe, at a certain depth, become so entirely changed, as to afford no satisfactory data as to any antecedent period. In no department of natural science is the admirable caution of the philosopher more necessary than in geology,—" that we should remember, knowledge is a temple, of which the vestibule only has been entered, and we know not what is contained within those hidden chambers, of which the experience of the past can afford us neither analogy nor clue."

46. FINAL CAUSES.—Geology, then, does not affect to disclose the first creation of animated nature; it does not venture to assume that we have 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."*

The new page in the volume of natural religion, which Geology has supplied, has been so fully illustrated by Dr. Buckland, in his celebrated Essay, that I need not dwell at length on the evident and beautiful adaptation of the organization of numberless living forms, through the lapse of indefinite periods of time, to every varying physical condition of the earth, and by which its surface was ultimately fitted for the abode of the human race.

* Bishop Butler.

We have seen that the infusoria lived and died in countless myriads, and furnished the tripoli and the opal—that river-snails and sea-shells elaborated the marble for our temples and palaces, and polyparia the limestone of which our edifices are constructed; and that grass, herb, and tree, have been converted either into materials to enrich the soil, or a mineral which should serve as fuel in after ages, when such a substance became indispensable to the necessities and luxuries of civilized man. Thus it is that geology has thrown a new interest around every grain of sand, and every blade of grass; and that the pebble, rejected by the moralist and the divine,* becomes in the hands of the philosopher 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 designed to contribute to our physical necessities and gratifications?—Say, rather, that this display of beauty, power, and goodness, was designed to fill the soul with high and holy thoughts—to call forth the exercise of our reasoning 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 instructed to hope may be our portion hereafter!

* Paley. The remark alludes to the celebrated argument of this distinguished author.

47. Geological theory of Leibnitz.—If we extend our views beyond the limits of strict induction, and venture to speculate on the condition of our globe in the dawn of its existence, and in those remote periods of which the physical characters are inscribed on the rocks and mountains, it appears to me that the theory of Leibnitz, which embraces the *original nebular condition of the solar system*, and assumes a former incandescent state of this planet, and its gradual refrigeration, is the only hypothesis in harmony with the present state of astronomical and geological knowledge. The prevalence of a higher temperature in northern latitudes during the deposition of the secondary formations, was indicated by the fossil remains of animals and plants of a tropical character (see page 435). If we admit of a progressive cooling of the earth, we necessarily infer that in the most ancient epochs, the influence of the internal heat upon the earth's surface was very considerable, and that it gradually decreased, till it arrived at the present condition of things, in which the surface temperature is scarcely, if at all, affected by radiation from within. Assuming then as an established theory, what at present, perhaps, must only be regarded as a highly philosophical and probable speculation, we can readily understand that during the secondary geological eras, the temperature of the surface may have been so augmented by a supply of heat from an internal source, as to have maintained a climate possessing the conditions

required for the existence of corals in the seas, and of forests of palms and tree ferns, and swarms of reptiles, on the islands and continents of northern latitudes.* The climate of particular latitudes would also be materially influenced by the great changes in the relative proportion of land and water, which took place in different geological periods. Thus, as Mr. Lyell has satisfactorily demonstrated, the dry land in the northern hemisphere has been on the increase since the commencement of the tertiary epoch; not only because it is now greatly in excess beyond the average proportion which land generally bears to water on our planet, but also that a comparison of the secondary and tertiary strata, affords indications throughout the space occupied by Europe, of a transition from the condition of an ocean interspersed with islands, to that of a large continent; and this increase of the land may in some measure have contributed to that gradual diminution of temperature which the organic remains denote.†

48. ASTRONOMICAL RELATIONS OF THE SOLAR SYSTEM.—Having thus endeavoured to interpret the natural monuments of the earth's physical history, let us contemplate the relation of our solar system to the countless orbs around us. For while astronomy explains that our system once existed as a diffused nebulosity, which passing through various

* See an excellent summary of the present state of geological theory in Phillips's *Treatise on Geology*.

† Lyell's Principles of Geology, vol i. chap. vii.

states of condensation, formed a central luminary, and its attendant planets; it also instructs us, that it is but one inconsiderable cluster of orbs, in regard to the group of stars to which it belongs, and of which the milky-way appears to be, as it were, a girdle; the solar system being placed in the outer and less stellular part of the zone.* But the astounding fact, that all our visible universe is but an aggregation, a mere cluster of suns and worlds, which to the inhabitants of the remote regions, that can be reached 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 on the mind a feeling 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!

Again, when conducted by our investigations to the invisible universe beneath us, the *milky-way*, and the *fixed stars*, of animal life, which the microscope reveals to us, we are overpowered with the contemplation of the minutest as well as of the mightiest of His works! And if, as an eminent philosopher observes, our planetary system was gradually evolved from a primeval condition of matter, and contained within itself the elements of each subsequent change, still we must believe, that every physical phenomenon which has taken place,

* See Mr. Whewell's Bridgewater Essay.

from first to last, has emanated from the will of the Deity.*

49. CONCLUDING REMARKS.—With these remarks, I conclude 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 but from 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 and enduring love and admiration of natural knowledge, which I feel in my own,—or have illuminated 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 remain for ever; and, by con-

* Professor Sedgwick.

ducting to new and inexhaustible fields of inquiry, prove a never-failing source of the most pure and elevated gratification.

It is indeed 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!" *

For to one imbued with a taste for natural science, Nature unfolds "her hoarded poetry and her hidden spells;" for him there is a voice in the winds, and a language in the waves—and he is

—— "Even as one,
Who, by some secret gift of soul or eye,
In every spot beneath the smiling sun,
Sees where the *springs of living waters lie!*" †

* Wordsworth. † Mrs. Hemans.

Note.

GEOLOGY, beyond almost every other science, offers fields of research adapted to all capacities, and to every condition and circumstance in life in which we may be placed. For while some of its phenomena require the highest intellectual powers, and the greatest acquirements in abstract science, for their successful investigation, many of its problems may be solved by the most ordinary intellect, and facts replete with the deepest interest may be gleaned by the most casual observer.

To the medical philosopher Geology presents peculiar attractions for those hours of leisure and relaxation, which are indispensable to maintain a healthy state of mind; for it requires the cultivation and application of chemistry, botany, comparative anatomy, zöology, and physiology—sciences which form the very foundation of medical knowledge. It exerts, too, the most salutary influence, by calling forth the continual exercise of our intellectual powers; for the desire to explain what is obscure in the natural records of the past, induces a more accurate examination of existing physical phenomena, and of the organization and habits of the living beings within the reach of actual observation. It enforces the necessity of weighing the conflicting evidence of apparently irreconcileable phenomena, of detecting differences, or seeking analogies, and of generalizing and combining an immense number of isolated facts. The mind thus acquires the power of acute observation, of patient investigation, and of salutary caution in drawing inferences and arriving at conclusions—habits of the first importance in the discrimination and treatment of diseases. I therefore entreat my medical brethren not to be deterred from the pursuit of so legitimate a source of the most elevated gratification, by the apprehension lest their professional success should be retarded by a reputed taste for science. Happily the time is now arrived, when the empty boast of possessing *only* professional knowledge, is no longer considered a proof of superior medical skill, but, on the contrary, an unequivocal acknowledgment of limited acquirements, and evidence of contracted and imperfect views of the subjects embraced by medical philosophy. They may rest assured that the practitioner who, by the exercise of his reasoning powers in scientific investigations, is capable of comprehending the laws by which organization and vitality are governed, and is thus enabled, not by mere habit or conjecture, but by cautious induction, to trace the phenomena observable in aberrations of health to those organs on whose functional or structural derangement they may depend, but with which they may appear to hold but obscure or uncertain relations, will ultimately meet a sure reward in the confidence and approval of the unprejudiced and the intelligent. In this, my last public attempt to encourage a taste for scientific pursuits, I may be permitted to allude to my own successful medical career, in proof that the pursuit of science is not incompatible with a deep devotion to professional duties; and I will venture to add, not from vanity or presumption, but from an earnest desire to remove the apprehension which, I know, deters many medical practitioners from pursuits so congenial to their taste and education, that so far from my known scientific predilections having proved injurious to my professional prospects, they have, on the contrary, largely contributed towards my success, by affording introductions which otherwise would not have been within my reach; independently of the privilege, which in my estimation is beyond all price, that of being permitted to hold communion with the most eminent philosophers of our times.

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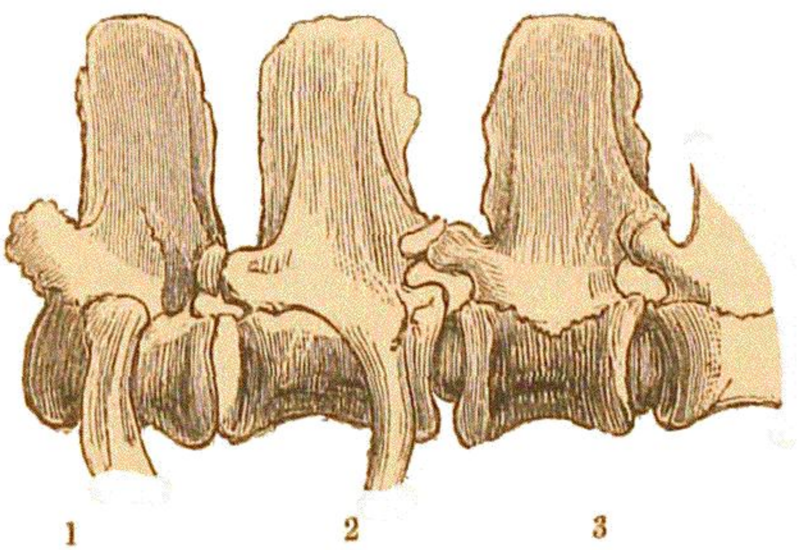
APPENDIX.

M. Page 486.—ON A PECULIARITY OF STRUCTURE IN THE FIRST CAUDAL VERTEBRA OF THE ADULT GAVIAL.—The discovery of the Swanage crocodile induced me to institute a rigorous examination of the skeletons of the recent gavials in the museum of my friend Dr. Grant, of the London University, with the view of determining the affinities of the fossil remains. In the course of my investigation I detected a peculiar conformation in the *first caudal* or *coccygeal* vertebra of the recent gavial, which, strange to say, appears to have escaped the notice of previous observers. The vertebræ of the existing crocodilian family are invariably concave in front, and convex behind; but the *first caudal* (3) in the adult gavial is *doubly convex;* and the last sacral vertebra (2) *concave posteriorly*, to receive the anterior convexity or ball of the caudal. These peculiarities are shown in the annexed sketch.



TAB. 153. SACRAL AND CAUDAL VERTEBRÆ OF THE GAVIAL.

Figs. 1, 2. The sacral vertebræ. 3. The first caudal or coccygeal vertebra, which is doubly convex.

The last *cervical* vertebra in turtles and tortoises has a similar structure. In a very young gavial in Dr. Grant's collection, the sacro-coccygeal surfaces are as flat as in the vertebræ of mammalia; while in the crocodile and alligator, of the same early period, the coccygeal vertebra is convex in front, as in the adult gavial. This mechanism confers the power of free motion without risk of dislocation or mutilation. The importance of a knowledge of this fact to the palæontologist is too obvious to require remark; the discovery in the Tilgate grit of a caudal vetebra, having both the extremities convex, would, I must confess, have been very perplexing, previously to my examination of the adult gavial.

N. Page 566.—Rev. J. B. Reade, F.R.S. &c. on Fossil Infusoria; in a letter to the Author.

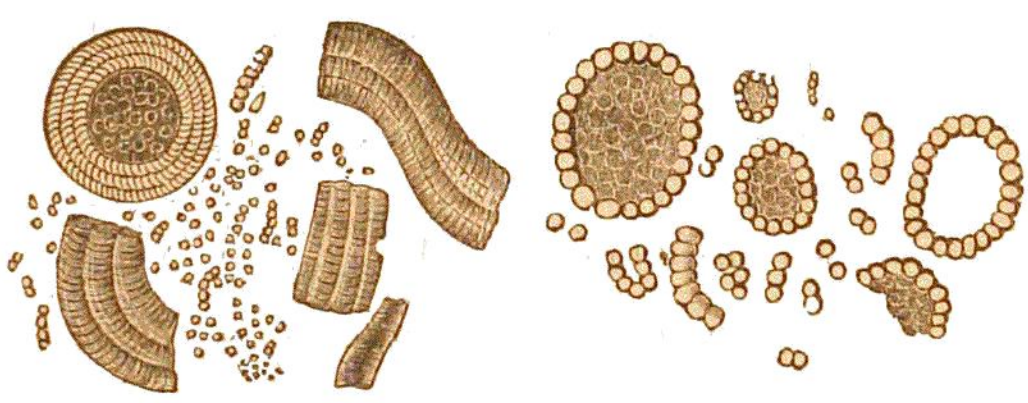
My dear Sir,

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 among 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 page* 647). I premise this remark, because it enables me to reply to your query, respecting the existence of 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 silicious 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 silicious 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 characterised by its own minute living forms; and you, yourself, had more than once contended for the existence of life during the granitic period. 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 it will baffle our utmost ingenuity to remove; for, though, on the one hand, I meet with silicious 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 organisms. 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, as in chalk, 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*.

The "Philosophical Magazine" for April, 1837, to which my attention has been recently directed, contains, under the article "Palæontology," a short note by Professor Ehrenberg, on the organic forms which he had observed during an exact microscopic analysis, several times repeated, of upwards of a hundred minerals of different groups; and in the valuable papers of the same author, published originally in "Poggendorf's Annalen," and lately given to the English reader in "Scientific Memoirs," Vol. I. part iii. it is observed, with respect to *Gaillonellæ*, and other species of animalcules, that their proportion merits a passing attention. "The millions of the tribes of infusoria have often been mentioned and spoken of, almost without consideration of their number, perhaps because little belief is entertained of their corporeality. But since the Poleirschiefer of Bilin must be acknowledged to consist almost entirely of an aggregation of infusoria, in widely extended layers, without any connecting medium, these animals begin to acquire a greater importance, not only for science, but for mankind at large. A cubic inch of the Poleirschiefer would contain, on an average, about 41,000 millions of the *Gaillonellæ;* and the silicious shield of each animalcule weighs about the 1-187 millionth part of a grain."

Explanation of the Figures (Tab. 154, 155,) drawn under a magnifying power of about 500 linear.

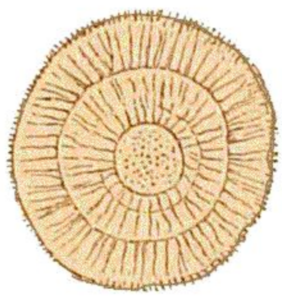


TAB. 154—BODIES IN PORCELAIN EARTH AND CHALK (*highly magnified.*)

Fig. 1. Form of porcelain earth, exhibiting concentric articulated rings; entire and in fragments.

Fig. 2. Chalk: the elementary molecules articulated in the form of rings; entire and in fragments.

Professor Ehrenberg observes, that "mica and quartz present *a granulated appearance of great regularity*, either without their outer surface of fracture undergoing any previous preparation, or after having been warmed or heated to redness."



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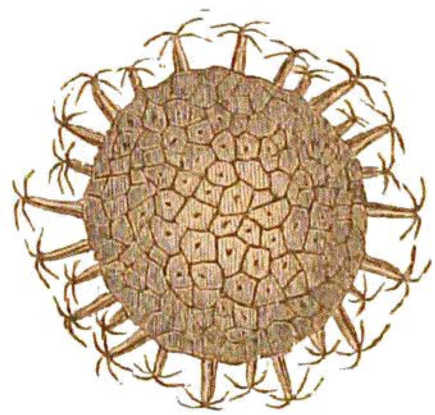

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TAB. 155.—INFUSORIA IN FLINT (*highly magnified*).

Fig. 1. Body unknown—formed of three distinct circles: the intervening spaces are filled with numerous delicate rays, and the exterior circle is sinuous and fringed. From the flint of Sydenham in Kent.

2. *Xanthidium furcatum* of Ehrenberg; in a flint, from Sydenham.

From the researches of Professor Ehrenberg, we may regard as ascertained facts, that the following rocks and mineral substances consist entirely, or partly, of the shields or cases of infusoria: viz.

1. Bergmehl 2. Kieselguhr	Newest formations.
3. Poleirschiefer 4. Saugschiefer 5. The semi-opal of the Poleirschiefer	Tertiary formations.

The following species of stone are *very probably* of the same nature:

6. The semi-opal of the Dolerite 7. The (precious) opal of the Porphyry 8. The flint of the Chalk	Secondary and primary formations.

It is gratifying to know that Professor Ehrenberg is still engaged in a close examination of the remarkable characters of the primary formations, and that he has announced his intention to publish the results, when sufficiently matured.

Believe me to be, my dear Sir,

Very faithfully yours,

PECKHAM, *Dec.* 1837. J. B. READE.

P.S. *Dec.* 1838.—XANTHIDIUM.—(Etym. *ξανθὸς, yellow.*)

This genus, forming one of the numerous family of the *Bacillariæ*, was founded in the year 1832, on three species described in the Transactions of the Berlin Academy. Many new species, both recent and fossil, have been now discovered. They are characterised by a silicious shield, simple or set with spines. It appears probable that the spines or tubes surrounding the body in some of the fossil species, were supplied with cilia. Propagation by self-division is their mode of increase, and is at once a proof of their animal nature; the specimen represented Tab. 108, (a recent *Xanthidium furcatum*) shows the commencement of this process. The genus *Gaillonella* also belongs to the family of *Bacillariæ;* its principal characters are a simple silicious shield, cylindric, globose, or discoidal, and occurring in chains—(see Tab. 109.)

O. Page 566.—EHRENBERG ON INFUSORIA.—To the above interesting communication of Mr. Reade, I will add the following abstract of Ehrenberg's observations on this subject.

This eminent observer has determined twenty-eight fossil species of infusoria, all belonging to the family of the *Bacillariæ*. Of these, fourteen species are undistinguishable from existing fresh-water, and five species from marine infusoria; the others belong to extinct or unknown forms. The great sharpness of the outlines of all these silicious shields appears to have been produced by intense heat, by which all organic (particularly vegetable) carbon has been dissipated; for some of these animals, like existing species, must have lived on plants. Different kinds of the minerals containing the fossil infusoria have a preponderance of different species. The polishing slate or tripoli of Bilin, consists almost entirely of an aggregation of infusoria in layers, without any connecting medium; and of this stone about 50 cwt. are consumed annually at Berlin. The size of a single specimen of these infusoria is equal to 1-6th of the thickness of a human hair: as the stone is slaty, but without cavities, the animalcules lie closely compressed. About 23 millions of these creatures would make up a cubic line; and in a cubic inch there would be 41,000 millions, weighing 220 grains; the silicious shield of each animalcule weighs about 1-187 millionth part of a grain. The fossil animalcule of the iron ochre is only the 1-21st part of the thickness of a human hair; and one cubic inch of this ochre must contain *one billion* of the skeletons of living beings!

The *infusoria* rock of Bilin forms a bed fourteen feet thick, above a layer of clay which lies on chalk marl, beneath which are primary rocks. The upper beds of stone rest on a projected mass of basalt, which forms the Spitalberg; on the opposite side of which coarse limestone, with many crinoidea and other chalk fossils, lies on the gneiss. The harder masses, containing semi-opal, are situated in the upper part of the tripoli. A close microscopical analysis of the semi-opals from Bilin, which equal flint in hardness, shows that it consists partly of infusorial forms, held together by a small quantity of transparent silicious cement, and partly of single infusoria, but of a larger size, like insects in amber. From the power possessed by these animalcules, of secreting skeletons of iron, flint, and lime, the proverb, *Omnis calx e vermibus, omnis silex e vermibus, omne ferrum e vermibus*, seems likely to be verified in a very striking manner.*

Since the former edition of "The Wonders of Geology," a copy of Ehrenberg's splendid work on the infusoria† has been deposited by that illustrious naturalist in the library of the Royal Society. It is in one vol. folio, with

* Taylor's Scientific Memoirs, Vol. I. Part 3.

† Die Infusionsthiercen als Vollkommene organismen. Ein blick in das tiefere organische leben der Natur. Leipzig, 1838.

64 plates, containing many hundred figures, all coloured from nature. It is indeed a most extraordinary production, whether we consider the prodigious labour, profound knowledge, and eminent talents for observation required for the successful investigation of the subject, the surpassing excellence of the drawings, or the marvellous nature of the beings which are delineated and described. He who has not seen the work of Ehrenberg, can have no idea of the fantastic shapes, and almost endless diversity of form and structure, which animal existence assumes even in our own planet, in the regions from which the microscope has withdrawn the veil.

DESCRIPTION OF PLATE V.—*Frontispiece to Vol. II.*

Fig.

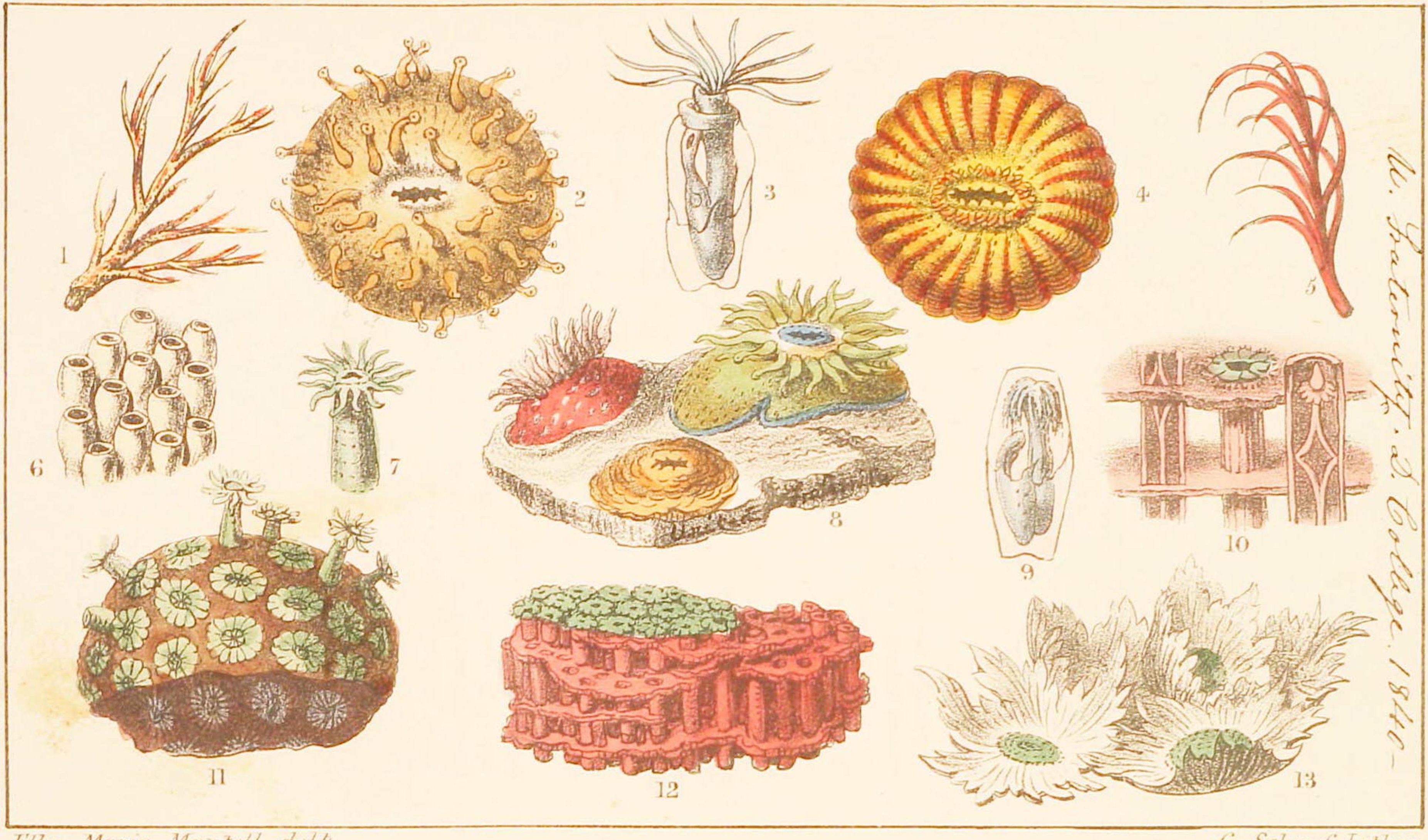
1. *Gorgonia patula;* magnified view of a branch, with six polypes expanded; p. 537.
2. *Campanularia gelatinosa;* a branch highly magnified; some of the polypes are protruded, and others within their cells; pp. 522, 535.
3. *Sertularia setacea;* a branch with three polypes expanded; highly magnified; p. 535.
4. *Meandrina cerebriformis,* as seen alive in the sea; one-thirtieth its natural size; p. 548.
5. *Pocillopora cerulea,* from the Indian seas; drawn when alive in the water; p. 545.
6. *Flustra pilosa,* encircling a piece of fucus; natural size; p. 533.
7. *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. 539.
8. *Alcyonium gelatinosum;* a portion highly magnified; some of the polypes are expanded, and others in various states of contraction; p. 558.
9. *Caryophyllia angulosa,* alive; from the American seas; half the natural size; p. 545.

DESCRIPTION OF PLATE VI.

Fig.

1. Branch of a *Gorgonia*, from the West Indies; p. 537.
2. *Fungia actiniformis*, from the South Pacific Ocean, as seen alive, and the polypes in activity; one-tenth the natural size; p. 545.
3. *Flustra pilosa;* a single cell, with the polypus protruding its tentacula; highly magnified; p. 522.
4. *Fungia rubra*, as it appears alive in the water; one-twelfth the natural size; from the Ladrone Islands; p. 545.
5. Branch of a *Gorgonia*, from the Mediterranean; p. 537.
6. A minute portion of a *Flustra*, highly magnified, to show the form and arrangement of the cells; p. 521.
7. A single detached polype of *Astrea viridis*, highly magnified; p. 546.
8. A group of living *Actinia*, or sea animal-flowers; Brighton; p. 542.
9. Polype of a *Flustra* retracted within its cell; p. 521.
10. Three connected tubes of *Sarcinula musicalis*, magnified, to show the internal structure; p. 540.
11. *Astrea viridis*, represented as alive in the sea; some of the polypes are expanded, and others contracted; p. 546.
12. *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. 540.
13. *Pavonia lactuca;* a group of four cells, each cell containing a beautiful green polype; from the shores of the South Sea Islands; p. 546.

Pl. VI



Ellen Maria Mantell delt.

G. Scharf Lithog.

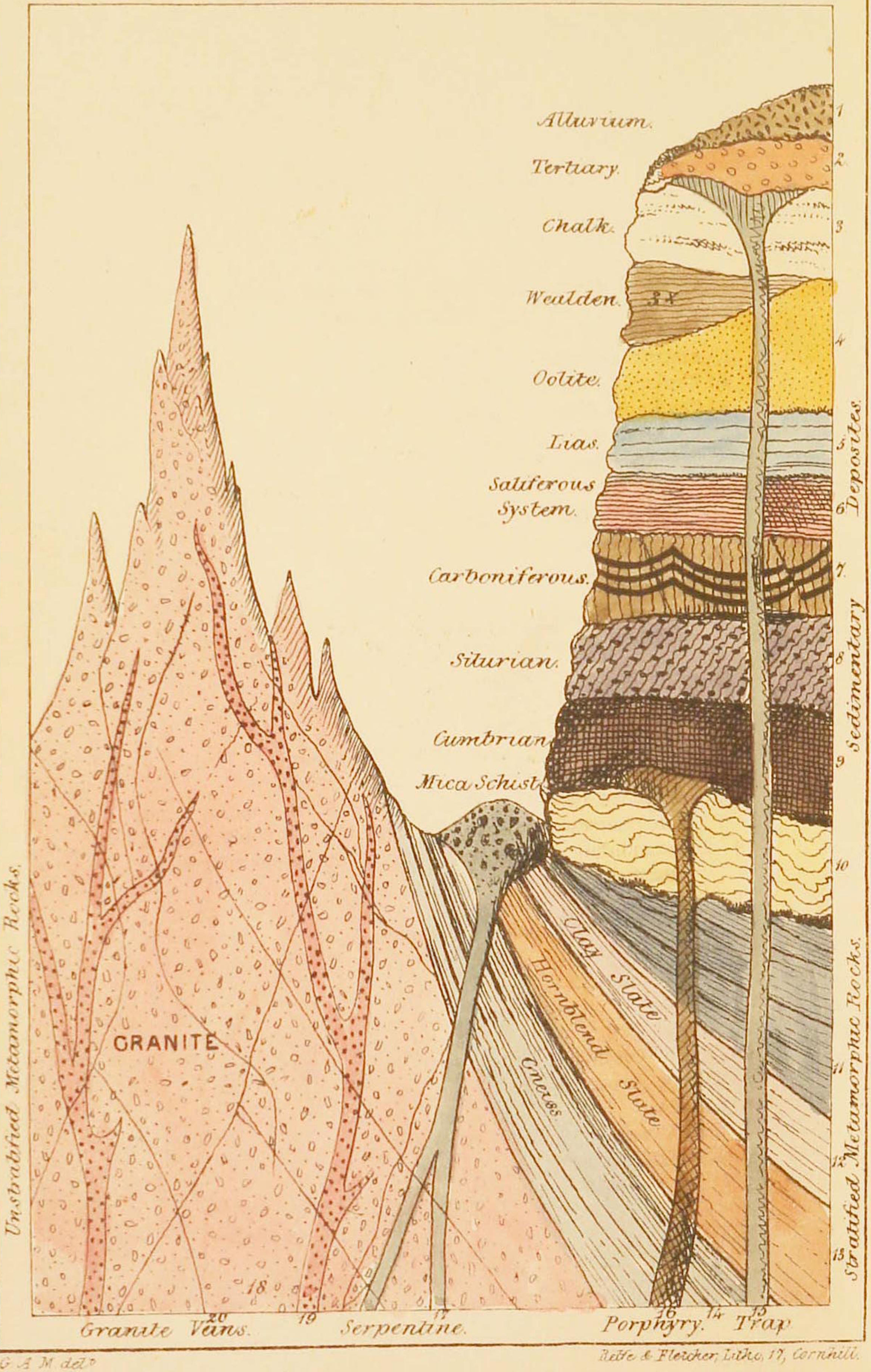
DESCRIPTION OF PLATE VII.

Theoretical Arrangement of the Rocks which compose the Crust of the Earth; p. 194.

1. Alluvial deposits.
2. Tertiary formations.
3. Cretaceous system, comprising the
   Chalk, with and without flints,
   Chalk marl,
   Galt,
   Shanklin sand.

3*. The wealden.

4. The oolite.
5. The lias.
6. Saliferous system, consisting of,
   1. The new red sandstone,
   2. Magnesian limestone.
7. The carboniferous system, namely,
   The coal-measures,
   The mountain, or carboniferous limestone,
   The old red sandstone, or Devonian system.
8. The silurian system, consisting of the Ludlow rocks, Dudley limestone, Caradoc sandstone, Landeilo flags, Trilobite slate, &c.
9. The Cambrian system, consisting of the series of greywacke and slate rocks.
10. Mica schist.
11. Quartz rock and primary limestones.
12. Clay slate.
13. Hornblende slate.
14. Gneiss.
15. Dike of Trap.
16. Dike of Porphyry.
17. Dike of Serpentine, &c.
18. Granite.
19. Granite veins.
20. Metalliferous veins.



G A M del^o

Reeve & Fletcher, Litho, 17, Cornhill.

DESCRIPTION OF PLATE VIII.

I. Section of a volcanic cone, formed of scoriæ and lava. A bed of alluvial detritus (coloured *sienna*) covers the flanks of the principal cone, as in the Isle of Ascension, Iceland, &c.

II. Volcanic mountains in Auvergne, from Mr. Scrope. Part of the southern chain of Puys, exhibiting the broken craters of Chaumont, each with a lava current issuing from its base; see p. 258.

1. Montchal.
2. Puys de Montgy.
3. Montjughat.
4. Mont Dome, in the distance.

III. Environs of Clermont, from Mr. Scrope; *vide* p. 258. The town of Clermont is seen in the valley; in front is a basaltic peak, on which is built the castle of Montrognon. The green on the hills denotes the basaltic platform, which caps hills of fresh-water limestone. The distant outline is the granitic escarpment forming part of the boundary of the plain of Auvergne.

IV. Hills capped with basalt; Ardêche. View of the lateral embranchments of the basaltic platform of the Coiron, in Ardêche; see p. 258.

The beds of basalt, between three and four hundred feet in thickness, are spread over limestone strata, which, together with the basalt, were once continuous, but have been eroded and carried away by alluvial action.

V. Section of the cascade of Mont Dor; see p. 261. 1. Porphyritic trachyte; *volcanic*. 2. Tufa; a deposit from fresh-water. 3. Basaltic phonolite. 4. Breccia, composed of volcanic fragments. 5. Basalt. 6. Tufa, with veins of basalt.

VI. Section in the Isle of Rathlin. Eruption of trap through chalk; p.751.

Figs. 1, 3. Trap dikes; the chalk between the dikes, and on each side of the walls, to an extent of several feet, is changed into granular marble.

Fig. 2. A vein of trap traversing altered chalk.

VII. Eligug* Stack; a range of cliffs, composed of carboniferous limestone, in which the strata have been contorted by elevatory movements, and the upper part removed by denudation; from Mr. De la Beche.

Granite on chalk, near Weiss, in Saxony. This section shows that the metamorphic rock has been erupted since the deposition of the chalk, and has flowed over the cretaceous strata on which it reposes.

Trap with sandstone, at Strathaird. Vertical dikes of trap intersecting horizontal strata of sandstone; p. 753.

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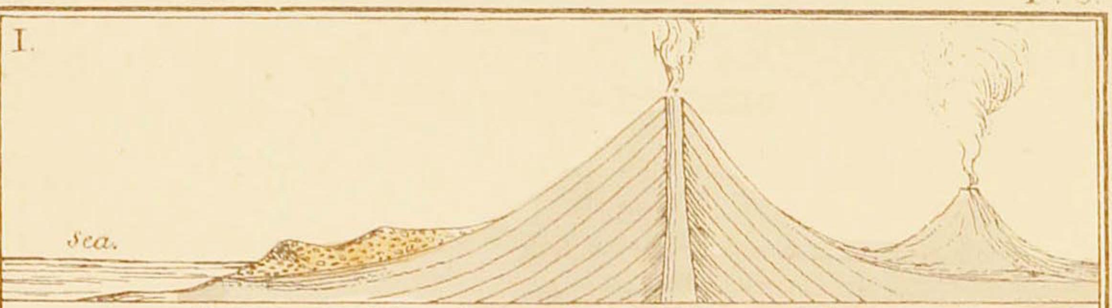
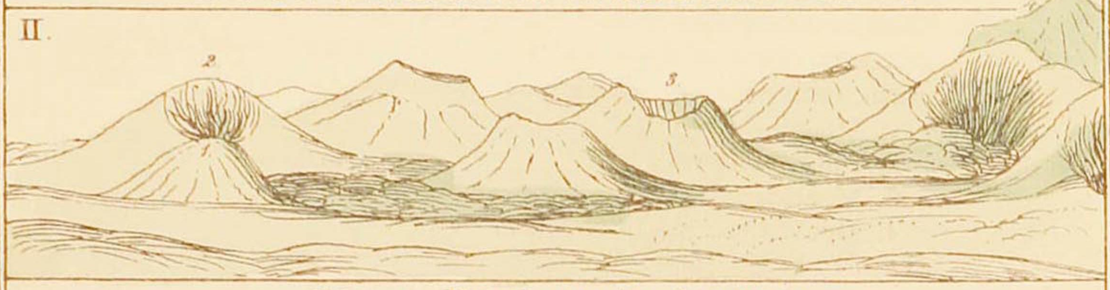
* Eligug—so called from the number of sea fowls, principally the Eligug (*arca torda*), which frequent it.

I.



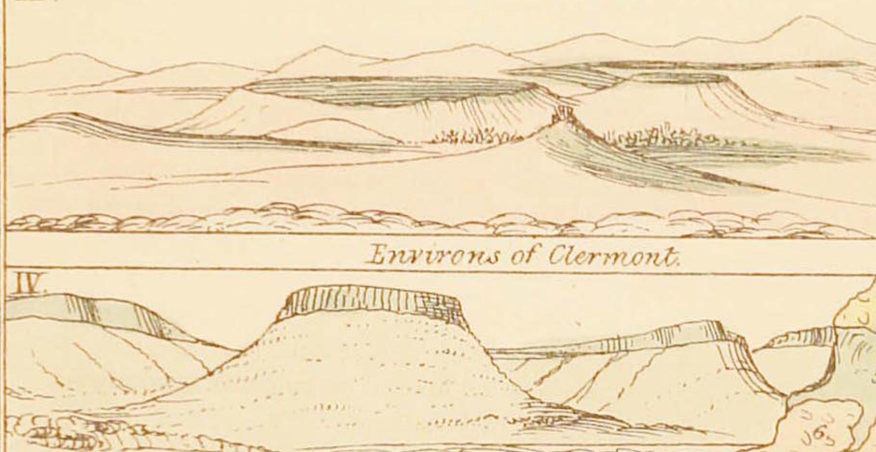
Section of a Volcanic Cone formed of Lava & Scoriæ.

II.



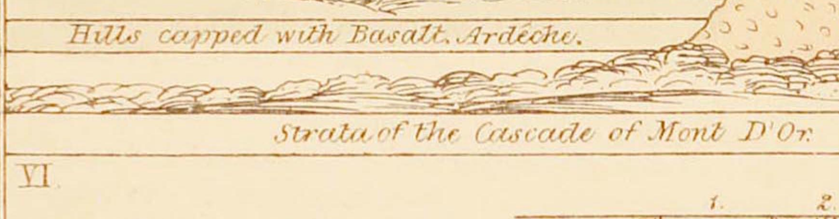
Volcanic Mountains in Auvergne.

III.



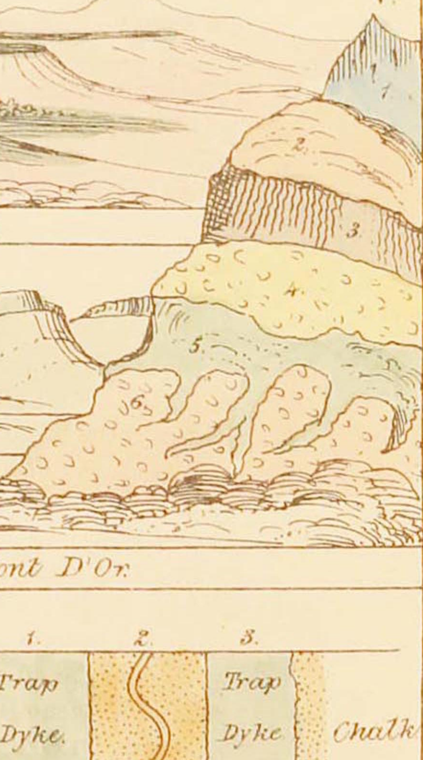
Environs of Clermont.

IV.



Hills capped with Basalt. Ardèche.

V.



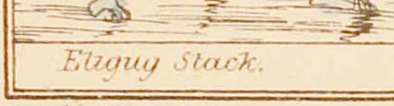
Strata of the Cascade of Mont D'Or.

VI.

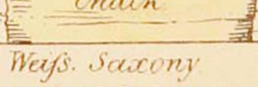
Section in the Isle of Raghlin.

Chalk changed into Marble.

VII.



Eliguy Stack.



Weiss. Saxony

Trap at Strathaird.

G. A. M. del.

Reife & Fletcher: Litho, 17, Cornhill

DESCRIPTION OF PLATE IX.

I. Section from the South to the North Downs, through the weald of Sussex; see p. 343. 1. Upper and lower white chalk, and chalk marl. 2. Galt. 3. Shanklin sand. 4. Weald clay. 5. Tilgate and Hastings strata.

II. Section of the Mendip hills; see p. 599. 1. Old red sandstone. 2. Carboniferous limestone. 3. New red sandstone. 4. Lias. 5. Inferior oolite.

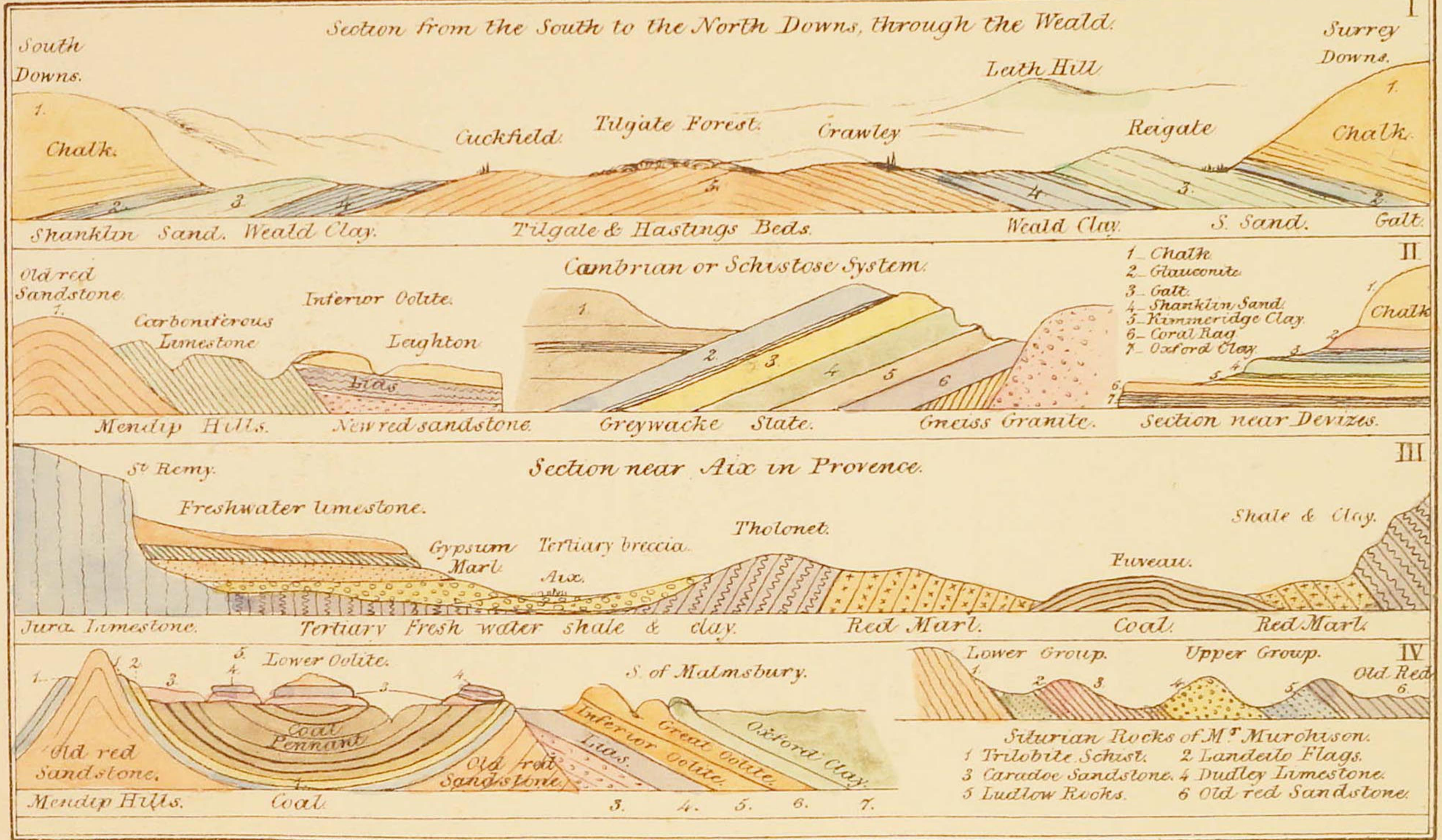
Cambrian or schistose system of Professor Sedgwick, p. 699; from Pl. 1, Encyclop. Metrop. 1. Carboniferous system. 2. Greywacke slate, with shells. 2*. Limestone, with coral and shells. 3. Green slate. 4. Red argillaceous rock and dark clay slate. 5. Chiastolite slate. 6. Hornblende slate. 7. Gneiss. 8. Granite.

Section near Devizes; see p. 442. 1. Chalk. 2. Glauconite, or firestone. 3. Galt. 4. Shanklin sand. 5. Kimmeridge clay. 6. Coral rag. 7. Oxford clay.

III. Section near Aix, in Provence, by Mr. Lyell and Mr. Murchison; see p. 245. 1. Jura limestone—equivalent to the oolite. Tertiary blue limestones and marls. 2. Tertiary red marls. 3. Tertiary coal. 4. The tertiary beds repose unconformably on the Jura limestone, and consist, on the north of the valley of Aix (the left side of the section of):—1. Breccia or conglomerate. 2. Foliated marls. 3. Gypsum. 4. Freshwater limestone. On the south, towards Fuveau, red marls, limestones, and shale, with coal fit for fuel, occur as in the section.

IV. Coal basin of Somersetshire; see p. 599; from Mr. Conybeare. Old red sandstone of the Mendip hills. 1. Carboniferous limestone. 2. Millstone grit. Coal—and Pennant grit. 3. New red sandstone. 4. Lias. 5. Inferior oolite. 6. Great oolite. 7. Oxford clay—south of Malmsbury; see p. 443.

Silurian system of Mr. Murchison; p. 696. 1. Trilobite slate. 2. Landeilo flags. 3. Caradoc sandstone. 4. Wenlock (Dudley) limestone. 5. Ludlow rocks. 6. Old red sandstone.



G. A. M. del^t.
Rolfe & Fletcher, Litho. 17, Cornhill

DESCRIPTION OF PLATE X.

A Geological Map of England, reduced from Mr. Bakewell's, and slightly modified. It serves to illustrate the general distribution of the various groups of strata or formations over England: namely—

1. Tertiary.
2. Upper secondary.
3. Lower secondary.
4. Carboniferous system.
5. The transition, or silurian system.
6. The Cambrian and metamorphic, or primary rocks.
7. Alluvial deposits.

Section from Whitehaven to Durham, or from the Irish Sea, through Cumberland, to the North Sea; from Mr. Conybeare. It exhibits the succession of the formations from the Magnesian limestone to the Slate rocks; and the disruptions which have taken place in the strata of that part of England.

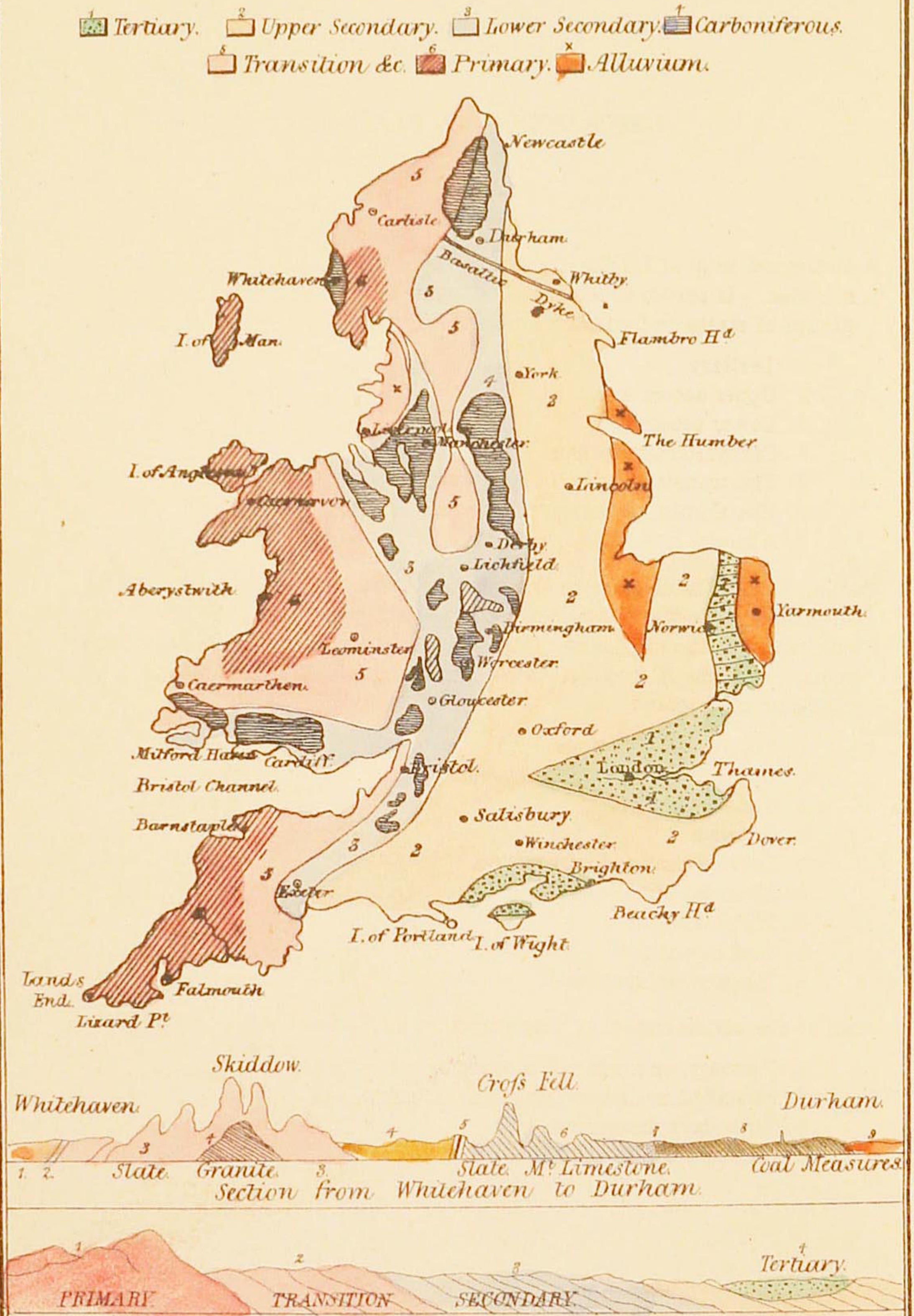
1. Magnesian limestone.
2. Coal and mountain limestone.
3. Slate.
4. Granite.
5. Broken coal and greenstone.
6. Mountain limestone.
7. Millstone grit.
8. Coal measures.
9. Magnesian limestone.

Plan of the stratification of England from north-west to north-east.

1. Primary, or unstratified metamorphic rocks.
2. Stratified metamorphic rocks, or transition series.
3. Secondary formations.
4. The tertiary.

Geological Map of England,

From Mr. Bakewell, by Miss Ellen Maria Mantell.



Ellen M. Mantell, delt.

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LIST OF THE WOOD ENGRAVINGS.*

VOLUME I.

LECTURE I.

LECTURE II.

LECTURE III.

* The whole of the Wood Engravings were executed by Mr. Wheeler, 14, Calthorpe-street, Gray's-inn-lane.

APPENDIX.

VOLUME II.

LECTURE V.

LECTURE VI.

LECTURE VII.

LECTURE VIII.

APPENDIX.

GLOSSARY.

*** *Explanations of many scientific terms not inserted in the Glossary, will be found in the text, by consulting the Index.*

Acephala .... Molluscous animals without a head, as the oyster, &c.
Acicular.............. Needle-like.
Aerolites.............. Mineral masses that fall from the atmosphere.
Algæ .... A family of marine plants.
Alluvium .... Water-worn materials.
Aluminum .... Metallic base of clay.
Alveola .... Sockets of the teeth.
Amorphous .... Shapeless.
Amygdaloid .... Cellular volcanic rocks, the cavities of which are filled with other substances.
Anastomosed .... Interlaced.
Anchylosed........... Joints of bones immoveably united.
Annelides .... Animals having an external integument formed of rings; as the worm.
Antennæ.............. The feelers of insects.
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.
Arenaceous .... Composed of sand.
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.
Astrea................. A genus of corals.
Augite................. A mineral found in many volcanic rocks.

Barytes .... Heavy spar: a mineral so called.
Basalt.................. Ancient lava, composed of augite and felspar; often columnar.
Basin .... A depression, or concavity in strata.
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.
Bitumen .... Mineral pitch or tar.
Brachiopoda .... Molluscous animals that move by arm-like processes.
Breccia .... Conglomerate of fragments of rocks.

Calc sinter .... Deposition from thermal springs charged with carbonate of lime.
Calcaire grossier .... A tertiary limestone.
Calcium .... Metallic base of lime.
Campanulariæ ...... Arborescent corals, with bell-shaped cells.
Cancellated .... Cellular, as the porous structure of 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.
Centrifugal .... A force directed from the centre to the circumference.
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.
Chelonia .... Animals of the turtle tribe.
Chert .... A silicious mineral allied to flint and chalcedony.
Choanite .... A zoophyte of the chalk.
Cilia .... Hair-like vibratory organs.
Cirrus .... A fossil turbinated shell of the chalk.
Clavated .... Club-shaped.
Coleoptera .... Insects having wing-cases, as beetles
Conchoidal............. Shelly.
Concretion .... A coalition of separate particles.
Condyle .... An articulating surface of a joint.
Conformable .... Applied to parallel strata lying upon each other.
Conglomerate......... Fragments cemented together.
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 tertiary deposit; from a provincial term (used in Suffolk and Norfolk) to denote gravel.
Crater .... The vent of a volcano.
Crateriform .... Having the form of a crater.
Crenulated .... Knotched, or toothed.
Crinoidea .... Lily-shaped animals.
Crucial .... In form of a cross.
Crustacea .... Animals having an external crust or skeleton, as the crab, lobster, &c.
Cryptogamia......... Plants with concealed fructification, as mosses, ferns, &c.
Crystalline............ Presenting the structure of crystals.
Crystals .... Symmetrical forms assumed by mineral substances.
Cupreus .... Coppery.
Cyathiform............ Cup-shaped.
Cycadea .... A genus of plants allied to the palms and ferns.

Delta .... Alluvial deposits formed by rivers.
Denudation .... Strata exposed by the action of water.
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.

Earth's Crust ...... That portion of the solid surface of the earth which is accessible to human observation.
Echinodermata...... Animals having a prickly external integument, as the star-fish, sea-urchin, &c.
Echinus............... Sea-urchin.
Edentata .... (*Toothless;*) animals having no front teeth, as the armadillo.
Elytra .... Wing-cases of insects.
Encrinite .... A genus of lily-shaped animals.
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 .... Organic remains.

Fault .... Interruption of the continuity of strata with displacement.
Fauna .... The zoology of a particular country.
Felspar .... A mineral which enters into the composition of many primary rocks.
Ferruginous .... Impregnated with iron.
Flora .... The botany of a particular country.
Flustra .... A genus of polyparia.
Foraminifera ...... A division of zoophytes having a porous structure.
Formation............ A group, or series of strata, supposed to have been formed during one geological epoch.
Fungia .... A genus of corals.

Galt .... A provincial term, applied to the blue marl of the chalk formation.
Gelatinous .... Of the consistence of jelly.
Gneiss.................. A primary rock, allied to granite.
Gorgonia .... A genus of flexible arborescent corals.
Grallæ .... (*Stilts;*) applied to birds having feet like the heron.
Green-sand .... The lowermost member of the chalk formation.
Green-stone .... An ancient volcanic rock.
Greywacké............ Rock of a conglomeritic character, indurated by heat.
Grit..................... Granular calciferous sandstone.
Gypsum .... Sulphate of lime.

Hamite .... Hook-shaped shell of an extinct genus of cephalopoda.
Hemiptera .... Insects with wings, half horny, and half membraneous.
Homalonotus ...... (*Smooth-backed;*) name applied to a genus of trilobites, in which the lobes are indistinct.

Hylæosaurus ...... The wealden lizard; an extinct reptile, found in the sandstone of the weald.
Hymenoptera ...... Insects with membraneous wings.

Ichthyosaurus ...... Fish-like lizard; an extinct reptile of the lias, &c.
Iguana .... A lizard of the Indies.
Iguanodon........... Extinct colossal reptile, having teeth like the recent iguana.
Imbricated........... Laid over each other like scales.
Incandescent ...... Applied to mineral masses in a state of fusion.
Induction .... The derivation of a principle from facts.
Infusoria .... Microscopic animals that abound in infusions.
Insectivorous ...... Animals that live on insects, as the hedgehog.
Inspissated .... Dried up.
Invertebrated ...... Animals without a bony, flexible spine, or vertebræ; as worms, lobsters, &c.

Kimmeridge clay ... A blue clay of the oolite.

Lacustrine........... Belonging to a lake.
Lamellated .... Covered with thin plates or scales.
Laminæ.............. The thin layers of which a stratum is composed.
Lapilli .... Volcanic ashes, in which globular concretions prevail.
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.
Lophiodon........... Fossil animal allied to the tapir; so named from the eminences on its teeth.
Lycopodiaceæ ...... The family of club-mosses.

Madrepore........... A genus of cellular branched corals.
Mammalia........... Animals which give suck to their young.
Mammillated ...... Studded with mammillæ, or rounded protuberances.
Mammoth .... An extinct genus of quadrupeds allied to the elephant.
Marl .... Strata composed of lime and clay.
Marsupial .... Animals which carry their young in a pouch, as the kangaroo.
Marsupite .... A genus of crinoidea belonging to the chalk.
Mastodon .... An extinct genus of quadrupeds, allied to the elephant, having tuberculated teeth.
Matrix .... The substance in which a fossil is imbedded.
Meandrina .... A genus of corals, with meandering cells, as the brain-stone coral.
Medullary .... A term applied to the central pith in plants, and to the matter of the brain and spinal marrow in animals.
Megalosaurus ...... Gigantic lizard; an extinct saurian, allied to the monitor.
Megalonyx .... An extinct quadruped, allied to the sloth.
Meteorites .... Mineral masses which fall from the atmosphere.
Megatherium......... An extinct gigantic quadruped, allied to the sloth.
Mica .... A simple mineral, one of the component parts of granite.

Micaceous	Containing mica.
Miocene	Middle tertiary strata.
Molares	Grinding teeth.
Mollusca	Soft animals—destitute of a bony structure, as the oyster.
Monitor	A genus of lizards, inhabiting the tropics.
Monocotyledonous	Plants having seeds with but one lobe.
Multilocular	Many-chambered shells, as the nautilus.
Muschelkalk	A limestone of the New red sandstone formation.
Nacreous	Pearly.
Neuroptera	Insects having wings finely nerved, as the dragon-fly.
New red sandstone	A group of strata lying between the magnesian limestone and the lias.
Nodule	A rounded mineral mass, as flint.
Normal	Natural, or original condition.
Nucleus	A kernel, or point round which other materials collect.
Nummulite	An extinct multilocular shell, resembling a coin.
Obsidian	Glassy lava.
Occiput	The back part of the skull.
Old red sandstone	A group of strata lying between the carboniferous and Silurian systems.
Oolite	Limestone composed of an aggregation of spheroidal grains.
Ornithorhynchus	A genus of animals having the mouth produced into a beak like a bird.
Orthoceratite	A straight multilocular extinct shell.
Ossicula	Small bones.
Ovate	Egg-shaped.
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.
Paleotherium	Extinct quadruped allied to the tapir.
Paludina	A fresh-water snail.
Pectunculus	A genus of bivalve shells, resembling the common *arca*.
Peperino	A volcanic conglomerate.
Petroleum	Mineral oil.
Pisolitic	Having a structure resembling peas, agglutinated together.
Planorbis	A genus of fresh-water shells, of a discoidal form.
Polyparia	Corals.
Porphyry	An ancient igneous rock.
Precipitate	The chemical separation, and deposit in a solid form, of a substance held in solution by water.
Producta	A genus of extinct bivalve shells, found in the older secondary rocks.
Pterodactyle	An extinct winged reptile.
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 tribe.
Quartz .... A mineral composed of pure flint.
Quartzose .... Rocks composed of silex, or flint.

Ramose .... Branched.
Reticulated .... Resembling net-work.
Rodentia .... (*Gnawers*) an order of animals having teeth of a peculiar structure, as the rat, squirrel, &c.
Ruminantia .... Animals that ruminate, as the deer, ox, &c.

Saurian .... Belonging to the lizards.
Scaphite .... Extinct genus of cephalopoda, of a boat-like form.
Scoriæ .... Volcanic cinders.
Sedimentary .... Deposited as a sediment by water.
Septaria .... Nodules of clay, having crevices filled with spar.
Sertularia .... A genus of arborescent corals.
Shale, or *schist* ...... Slaty clay.
Silex .... Flint.
Silica .... The base of flint.
Silicious .... Flinty.
Silicified .... Changed into flint.
Silt .... Fluviatile deposit of mud.
Spatangus .... A genus of sea-urchin.
Spheroidal .... Oblate, or having the form of a spheroid.
Spirifera .... Extinct family of shells.
Stalactite .... Pendant masses of carbonate of lime.
Stalagmite .... Calcareous concretions formed on the floor of caves by dropping from the roof.
Stellular .... Having star-like forms.
Stratified .... Deposited in layers.
Stratum .... A layer of any deposit.
Syenite .... A species of granite in which *hornblende* supplies the place of *mica*.

Tentacula .... Feelers.
Tertiary............... Ancient formations, but newer than the chalk.
Testacea............... Shells.
Trachyte .... Lava chiefly composed of felspar.
Trap rocks............ Ancient volcanic rocks; the term derived from the Swedish, *trappa*, a stair.
Trilobites .... An extinct family of crustacea, the body divided by three lobes.
Tubipora .... Organ-pipe coral; corals composed of tubes.
Tuff..................... Earthy volcanic rock.
Turbinated .... Shells having a spiral, screw-shaped form.

Veins .... Fissures in rocks, filled up by mineral substances.
Vermes .... Worms.
Vertebrated .... Animals having a flexible, osseous, spinal column.
Vesicular .... Full of vesicles or cells.

Unconformable ... Strata lying in a different position to those on which they rest.

Zoophytes .... Animal-plants, a term applied to corals and other animals supposed to resemble vegetables in form.

INDEX.

C.

D.

E.

INDEX.

G.

H.

CORRIGENDA.

Vol. I. Description of Frontispiece, line 16 from bottom, for *tree* read *trees*.

— page 7, line 4 from the top, dele *present*.

— — 15, 4 from the top, for *disturbance* read *disturbances*.

— — 25, 7 from the top, for *nulcei* read *nuclei*,