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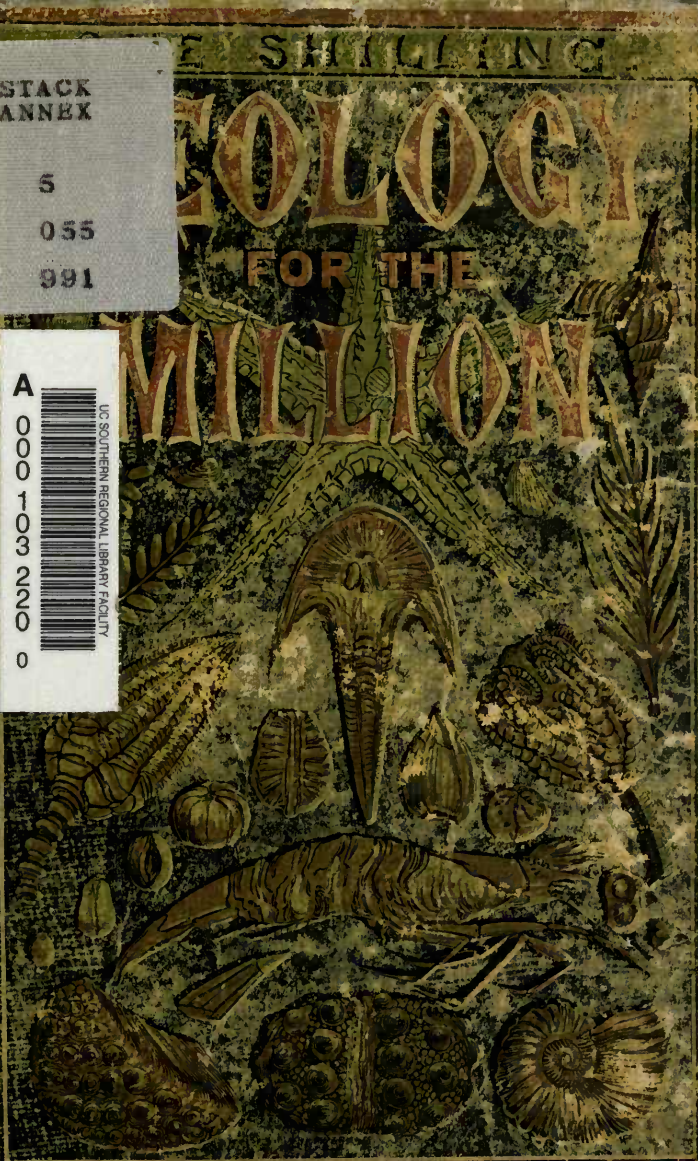
GEOLOGY FOR THE MILLION



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GEOLOGY

FOR

THE MILLION.

BY

MARGARET PLUES.

EDITED BY

EDWARD WOOD, F.G.S., F.R.S.L.

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GEOLOGY FOR THE MILLION.

CHAPTER I.

INTRODUCTORY.

"The Lord is a great God,
And a great King above all gods;
In His hand are the deep places of the earth,
And the strength of the hills is His also.
The sea is His, and He made it,
And His hands formed the dry land.

THE discoveries of science reveal to us that the "beginning" of this earth of ours was a fluid mass of fiery vapour, of intensely heated gas, "without form and void," rolling on and on, around its axis, receiving a globular form by the effect of its rotatory movement, and by its continued exposure in space gathering around it a thin crust, a rough uneven surface. Many geologists consider that the centre of the globe is filled with living fire at this day; this appears

probable from the many and careful experiments made in the deepest mines, where it is always found that the lower we penetrate the hotter it becomes. As the inner fire cooled gradually where it came in contact with the surface, the crust increased; this crust was constantly broken through or swollen in blisters by the heated matter within; but gradually through various agencies, which it will be the scope of this work to explain, it assumed the form of land and sea, mountain, plain, and valley, which is now familiar to our observation. This is God's work of creation, the agencies appointed and the results foreordained by Him. The length of time which He employed in this great work, is among the "secret things" which belong to Him; periods are indicated by the term "day," but we can attach no definite limit to these, seeing that "one day is with the Lord as a thousand years, and a thousand years as one day." The Book of Nature and the Scriptures of truth must of necessity be in harmony, seeing that the one is the acted will and the other the revealed word of Him who cannot lie. Any difficulties which *seem* to exist, arise out of our prejudiced minds and finite capacities; let us at once realize that "we know nothing yet as we ought to know," and be content to wait for God's further teaching to reveal to us the harmony between His acts and His words, and then every wonder of earth and every

revelation of heaven will lead us to a more child-like and rejoicing faith.

The first formation of crust on our globe constitutes the rock we call *Granite*, so named from the crystal *grains* of which it is composed. These crystals in simple granite are of three kinds, quartz, felspar, and mica; none of them rounded or water-worn, but angular or flaky, and closely compacted together. Quartz is pure silica; it is very hard, and more or less transparent, properly white, but often coloured pink or grey by the admixture of a little iron. The presence of other tints converts the substance into "precious stones," as the violet amethyst, the yellow topaz, the cinnamon cairngorm. Common quartz, occurring in veins or grains, is milk-white or glassy; mixed with other matters it makes jasper, flint, chalcedony, etc. Felspar consists of silica and alumina (sand and clay); it is sometimes white, but generally grey, reddish, yellowish, or greenish; it breaks into lozenge-shaped pieces, and its grains are distinguished from those of quartz by their flat shining surface, which a knife can scratch, though it takes no effect on the quartz. There are many varieties of felspar, and it is a useful rock in manufactures, enamel and china being formed from it. Mica is easily known by its glistening plates and scales; it consists of silica, alumina, iron, and potash; in other varieties

fluoric acid, magnesia, or lime enter into its composition.

Granite shows no traces of being deposited in water, but on the contrary its crystalline texture is a sign of its having cooled down from intense heat; it occurs in masses and veins, and when it bursts through the deposited rocks, it hardens the substance wherever it experiences its fiery contact. These outbursts were chiefly in the older age, but they occur in later formations, and there is no reason why they should not still recur.

The appearance of granite is very variable. Sometimes the crystal grains are large, sometimes very minute, sometimes they are closely pressed together, and sometimes very loosely. When mica is absent, and hornblende takes its place, the rock is called *Syenite,* while if talc prevails in the place of mica it is called *Protogine.* Graphic granite is formed only of felspar and quartz, the quartz forming lines like quaint letters. Several varieties of granite are often found in the same quarry. In colour it is generally some shade of grey, but when iron is intermingled, the rock assumes a rich red colour. The character of the country where granite rises to the surface is generally wild and bleak, the hills exhibiting a sameness of rounded outline, and the crags boasting little verdure; yet the great heights to which its hills attain, and the bold masses of the rocks, must ever strike us as very grand,—seen

in Cornwall, Wicklow, and Aberdeenshire; how much more when developed in mountain chains such as the Alps, Pyrenees, Andes, and Himalayas, where the granite rises in needle-shaped elevations, or strikes terror into the mind by its dark frowning precipices.

Its importance is attested both by Nature and Art. Whole systems of rocks are formed of its wasted particles deposited in layers in water. It is largely quarried in our own country, at Peterhead, Wicklow, and in Cornwall, being highly valuable for monuments, buildings, pavement, etc., from its durable nature.

Decomposed granite forms China-clay, and is exported in great quantities from Cornwall to the pottery districts.

Two kinds of rocks prevail in the crust of our globe, classed according to the agency employed in their formation. *Igneous rocks* are those formed by fire; *Aqueous rocks* those deposited in layers in water. These last are composed of weed and sand washed from the fire-formed rocks, and mingled with the remains of animal and vegetable life; they are also designated *Stratified rocks*, from the strata, or sheets in which the layers are spread out. The action of these powerful agents, fire and water, keep up the variety of configuration of the face of the earth, the one tending continually to lift up and roughen the crust, the other to wear down and smooth it.

Granite, whether gradually hardened into a continuous crust, or swelled up into the basis of mountain chains, or suddenly bursting through existing formations, takes its place at the head of igneous rocks. Being formed in the depths beneath, it is called a Plutonic rock, in contradistinction to the *Volcanic*, which are apparent on the surface.

The Trap rocks partake of the nature of the Granitic, as being both *Igneous* and Plutonic. The term *Trap* was taken from the Swedish *trappa*, a stair, because where these rocks prevail the hills have often a terraced appearance. The traps are generally seen breaking through the secondary strata, or heaving them up into domes, or spreading over them in sheets. Trap-dykes often appear as a continuous thread through wide areas; this we see exemplified in the dyke extending direct and purpose-like as that of a railway from the coast of Durham, near Hawthorne, into the middle of Yorkshire, and then dividing and running at an acute angle to the East coast of Yorkshire, between Whitby and Scarborough. Wherever these traps intrude, whatever their manner of appearance, they harden and crystallize the rocks with which they come in contact. In structure they are much varied, some being hard and crystalline, others earthy. Basalt and Greenstone are examples of the former, Claystone and Porphyry of the latter.

Basalt is the easiest to recognize of all the trap rocks, from its rising in columns, as exhibited in the pillars of the Giant's Causeway, and those known as "Samson's Ribs," near Edinburgh. There are, however, exceptions to this form of development, where it occurs in tubular masses. In colour it is dark, almost black, and contains green crystals and iron pyrites.

Greenstone is generally greenish black; in texture it is more *grained* than the basalt, partaking somewhat of the nature of granite. It is largely developed in Wales, Derbyshire, and among the Pentland Hills.

Claystone is buff, or reddish-brown, varying in tint to purple; it is chiefly composed of felspar, and looks like baked clay. When crystals of glassy felspar are imbedded in the mass it becomes *Porphyry*.

The scenery in a trap district is very picturesque, their frequent terraces being varied by cone-like summits and steep crags. The rocks do not form desirable building material, not being easy to shape into blocks, but they are very durable as road metal. Agates, jaspers, and cornelians, as well as "Scotch pebbles," are procured from them. In North America veins of copper occur in trap rocks.

Volcanic rocks mark the more recent effects of the internal fire. Gaining a vent when and where it may, it pours forth its melted rock as lava,

obsidian, pumice, scoriæ, or mud. Lava is mere melted rock; obsidian resembles glass; pumice is the solidified scum of the vast boiler; scoriæ are the cinders from the furnace;—these powdered form volcanic dust, and mingled with boiling water, volcanic mud. The Geysers, as well as the Volcanoes, belong to this class of agencies, and their heated waters hold sand and lime in solution, which is deposited upon their cooling. Mountains are formed or heightened, and islands raised out of the sea in incredibly short periods, by volcanic agency. In 1538, for instance, from Mount Vesuvius, stones and ashes were thrown up with a noise like artillery in immense quantities, and in four days their fall had formed a mountain in the valley between Lake Averno and Monte Barbaro, nearly as high as the latter, and measuring three miles in circumference. Many of the stones were as large as an ox. In an eruption in Iceland, in 1783, the ash-mud and lava were ejected in such quantities that it filled and overflowed a channel 200 feet broad and 400 feet deep. The opening at the top of a volcano is called a crater—it is sometimes cup-shaped and sometimes flat.

Earthquakes are another form of igneous action, and seldom occur in any extent where the imprisoned force has vent in volcanoes; the crust of the earth has frequently been upheaved along more or less extended areas during geological ages, sometimes causing great cracks, as in the

earthquake at Lisbon, but oftener raising the general level of the land without serious dislocation. Darwin says, "There is local antagonism rather than coincidence between direct elevation and volcanic action, and dislocations on a large scale are rare in volcanic districts."

We find the upheaving granite forming dome-shaped mountains, the shoulders of which are wrapped round with a rock, differing from, yet closely resembling it. This will generally be found to be one of a new group of rocks characterized as *Metamorphic,* and partaking of the character both of the Fire-formed and Water-formed classes, though they are now considered to belong to the latter. Indistinct lines of stratification in their masses give evidence of their having been originally deposited in water, while their more or less crystallized structure is equally symptomatic of the action of fire, whether developed as electric currents, glowing heat, or the presence of boiling water. They are also called Non-fossiliferous, or Azoic (no life), but this is a term of questionable justice. The absence of fossils is, to say the least, "not proven," while the presence of lime is adduced by some writers as a proof of the existence of organisms, though their traces are effaced—naturally, by the excessive heat to which the rock has been subjected. The component parts of the masses are the same as those of granite; indeed, it is evident that they are formed of the waste of

that ancient rock, deposited in water, the clay and sand being afterwards changed into crystalline rocks. This metamorphic formation occurs in immense masses. Professor Ansted suggests that in the gradual cooling and consequent contraction of the earth's crust, a series of wave-like motions were produced, causing a succession of elevations and depressions over an adjacent area, as is exemplified in the development of these rocks. They are often cracked and broken, and foreign matter is thrown into the cracks in a melted state, altering the texture, and traversing it with veins of metallic ore.

Four marked varieties exist in this group:—Gneiss, Mica-schist, Quartz-rock, and Clay-slate.

Gneiss is a hard, tough, crystalline rock, composed of quartz, mica, felspar, and hornblende, and marked with wavy lines of stratification; the crystals are not whole, as in granite, but broken and indistinct: it is also distinguished from granite in never sending out veins or dykes. Garnets are found in it.

Mica-schist is a flaggy or foliated rock. It consists of mica and quartz in alternate layers. When magnesia enters into its composition it is called Serpentine. It is well developed in the Lizard district; its richly variegated colours are thought to resemble the skin of a serpent, hence its name. It is soft, and yet receives a high

polish; hence it is much worked into ornamental articles. Chlorite-slate is another variety of mica, resembling it in texture, but coloured green. Quartz-rock is almost pure silica (sand) disposed in grains, and yet somewhat stratified, generally grey or pink, from the presence of iron.

Clay-slate is a fine grained rock, disposed in layers, which split into thin plates, but not in the direction of the strata. The splitting or "cleavage" is generally at an acute angle from the position of the layers, sometimes at a right angle. When coinciding with the layer it is an exception to the general rule. Roofing and other slate is procured from these rocks.

The Metamorphic group are well developed in the Scotch Highlands, also in Ireland, and among the Pyrenees and Alps. The districts where they prevail are rugged and irregular, and the utility of the rocks is not great. The limestones occurring among them produce good marble. The gneiss is applicable to rough building purposes. The quartz rock is available for the manufacture of crockery. Asbestos, occurring in silky threads, is useful for gas-stoves, and as fire-cloth. Pencil-lead is a product of some value; and amber and meerschaum deserve mention. The "precious stones" of the group are rock-crystal, garnet, and beryl. Far the most valuable member of the series is the clay-slate; to it we owe the best of our slates and slate-pencils, the roofs of our

houses, and our polished chimney-pieces, as well as the pavement for cisterns, &c. It is also rich in metals,—tin, copper, lead, silver, and even gold occurring in it; whilst iron, zinc, cobalt, and tin are found in the other rocks of the system.

We have now a granite crust upheaved in ridges, and bedded in with a thick deposit of metamorphic rocks, which traps have begun to penetrate, though they reserve their outbursts mainly for future ages. All is still bare and desolate, not a moss nor a lichen appeared on the naked skeleton of our globe, nor a sea-weed floated on the broad ocean. No trace yet existed, as far as we know, of animal or vegetable life,—everything was still with the absolute silence of death. The earth was prepared, and waited but the fiat of creation.

CHAPTER II.

SILURIAN SYSTEM.

CAMBRIAN.—WENLOCK.—DUDLEY.

"Nature alone is antique, the oldest art is a mushroom"
DARWIN.

IMMEDIATELY above the Metamorphic series lie extensive slaty and sandy rocks, in which the first dawn of animal life is detected. These prevail in the ancient Cambria (North Wales), and in Cumberland, and are named Cambrian. They are disposed in layers, which are bent and upheaved in every direction, like sheets of paper, subjected at once to pressure from the top and sides; and besides this twisting influence, they have been further disturbed by melted rock flowing over, or being forced through them. For some time these Cambrian rocks were supposed to be destitute of fossils, but this theory is now dis-

proved. In 1855, Mr. Salter discovered Trilobites and Worms in the Longmynd rocks of Wales, and Professor Rogers has since detected them in the Cambrians of America. Mr. Hugh Strickland found the Agnostus (a minute Trilobite) in the Llandeilo flags, and Professor Oldham discovered a Zoophyte in the still older schists near Dublin. This zoophyte was called after its first finder, *Oldhamia;* there are two species. When Sir R. Murchison was handling this fossil, he called the attention of those around him to it. "Look at it reverently," he said; "it is probably the first animal created." The same rock is developed in Wicklow and the South of Scotland. These Cambrian rocks are regarded by many geologists as the basement rocks of the Silurian formation, while others treat them as a separate system. Whichever name be chosen their position continues the same, lying between the changed rocks and the lime and clay of the Silurian group. We give the *Starry Oldhamia* as the most characteristic fossil (Pl. 1, fig. 1).

After the Cambrian formation we come to layers of shale, sandstone waved with ripple marks, limestone telling of corals and shells, and pebbly conglomerate, indicating ancient sea-beaches. Thus there arises to our mental view a vast ocean, beset with coral-reefs and mud-banks, in which trilobites and annelids burrowed; submerged rocks, to which stone-lilies were attached,

waving their numerous arms, and swaying their stony stems in search of prey; while the waters were peopled by quaint inhabitants, swimming back downwards, and ready to sink on the first suspicion of danger.

The aspect of Silurian districts in the present day is fairly pleasing; the hills would be dome-shaped, but, the arching strata being broken, gives them a camel-backed appearance; they are often well-wooded, and the surface soil turns with wet into a tough grey mud.

The Silurians of Ireland form eight separate groups, in each of which the fossils present marked distinctions. Conemara boasts a great variety, whilst at Bunowen there are no Crinoids or Gasteropods, but the *Atrypa Hemispherica* occurs in millions. This is a brachiopod, nearly allied to Rhynconella and Terebratula. It has a rounded shell, its growth marked by scaly lines; the hinge is not punctured as in Terebratula. The rocks of Kilbride contain corals and brachiopods in great variety. At Lisbellow the Orthoceratites abound, and the Graptolites (Pl. 1, fig. 2), their cells arranged in straight rows, single or double, along either side the stem, each cell the dwelling of one member of the compound inhabitant. The grey limestones of Kildare are fertile in trilobites and univalves, as Euomphalus and Nerita, and the darker rocks of Portrane are only productive of brachiopods.

No better district can be chosen for collecting and studying the fossils of the Silurian system than the banks of the Severn, near Coalbrookdale. Two delightful days spent in the quarries on Benthal Edge are among the happiest in my life. An elegant writer upon geology declares it as his opinion that "coral-hunting in the *débris* of a Wenlock-shale quarry ranks high among pleasures," and right cordially do I endorse his assertion. Some of these quarries were "worked out," and wild flowers and weeds had gained a footing there among the tombs of bygone generations, wild strawberries ripened against extinct corals, and short moss encroached on antique sea-shells. Other quarries had been more recently worked, and the stones were yet naked, while water filled the bottoms, although at so great an elevation above the bed of the Severn.

The Corals, of which I found a great number, were of the order distinguished as Cup and Star Corals. The animal or polyp is a simple jelly-like substance capable of spreading itself, and able to gather from the sea-water lime, wherewith to build a stony skeleton, which serves at once as its "home and its castle." Suiting the thread-like form of these polyps, the rooms of its house are simple tubes, the open end serving for its communication with the external world. Star-like ridges generally crown these tubes, taking their shape from the arms of the creature, as thus from its

door it extends them to catch its prey. This end of the tube is called a *cup*, and the starry rays are termed *septa*. To these septa we owe the beautiful pattern which covers the surface of these masses of fossil coral.

Though the Cup Coral is said to be "a simple cup," what I found were growing in clusters; and Mr. Roberts explains that they grow as buds out of the original cup, "giving a composite character to what was a simple polyp." Those in the Benthal quarry must have been great-grandfathers, for there were clusters upon clusters (*Cyathophyllum Articulatum*) (Pl. 1, fig. 6). There was a coral resembling the Brain Coral of our present seas; it was also massive (*Acervularia Ananas*). One with very beautiful starry septa, slender in its tubes and smaller than those I have described, was a Syringophyllum. The Mushroom Corals were represented in those quarries; one with a curved stem and star, containing thirty branched septa, was very abundant. Its scientific name is *Palæocyclus*.

I found Sun Corals (*Heliotes*) also; these belong to the division called Millepores. In examining these you should observe first the upper surface with the form of the cups and the number of the septa, then examine whether the tubes run down to the base, simple or branching, and whether the said base is free or endowed with a footstalk. The species of Sun Coral so abundant

at Benthal was like a sponge, the tubes closely set and the base free. I believe it was *H. Megastoma*. There were rudely-branched masses of coral belonging to the genus *Favosites*, simple bundles of tubes, forming large irregular lumps.

The oak-like branches of two species of Cœnites were frequent upon the masses of stone, but I could not detach them without their shivering; I have abundance of them in a small slab of Dudley limestone.

But the coral which best pleased the taste of my artistic companions was the Chain Coral; here the tubes are arranged in lines, which lines meet one another at every possible angle, so that the cups form an intricate pattern, suitable for ladies' embroidery (*Halysites Catenularia*) (Pl. 1, fig. 7).

Parasitical Corals were not wanting. I found shells sculptured with them in relief, just as we find them on the shores of our present seas.

Encrinital stems were there in great abundance, and portions of the head and arms. Here the animal is endowed with a stony stem, by which it adheres to the rock. In some species the arms are well developed, and indicate a relationship to the true Encrinites or Stone Lilies; in others the habit seems more like that of the Sea Urchin, only always rooted to the rock (Pl. 1, fig. 5). These latter are without arms, the animal enclosed in a case formed of stony plates, an opening left in the upper surface for the mouth, another near it for

the vent, and a third for the eggs. The mouth has a proboscis covered with small plates. The truer types of Encrinite had a stony cup and arms resembling the stamens of a flower which procured for the radiate animal the name of Stone Lily (Pl. 1, fig. 4).

The best known varieties in the Silurian rocks are the Cup (*Cyathocrinus*) and the Sculptured Encrinite (*Glyptocrinus*). Benthal Edge afforded a good variety of shells, and in these the system is as rich as in corals.

The largest number of Silurian shells belongs to the curious class *Brachiopoda*, so called because having the lower valve fastened to the rock, they were furnished with two long hairy *arms* by means of which to collect their food: when at rest these arms were coiled spirally within the shell; the valves were not connected by a hinge, but hairs passed through one valve from the other, and by them the animal was fixed to its rocky home. A little almond-shaped shell, showing a hole where the hinge of most bivalves is situated, I recognized as a Terebratula; and one of a rounder shape, the upper valve wrapping over at the back, and both upper and under valves deeply grooved, was evidently of the same genus. Others, with the back of the valves prolonged into wing-like processes and also minutely striated, were Spirifers; whilst a pretty oval shell, the under valve flat and

the upper convex and overlapping at the hinge, showed the characteristics of the Orthis.

Several genera of Cephalopoda, mollusks with true head, ears, and eyes, are found in the Silurian rocks, and two rewarded my search at Benthal Edge. Though nearly related to the Cuttle fish, these more closely resembled the Nautilus, their organization being of a lower order. Straight, narrow, rudely-sculptured fossils, resembling minute obelisks, proved to be remains of Orthoceratites (Pl. 1, fig. 10), the ridges showing where had been the chambers of the shell; while whorled fossils, which at first sight we took for Ammonites, but that really were, in fact, Lituites (Pl. 1, fig. 9), showed a still closer relationship to the Nautilus. Their form reminds you of the origin of their name, a *trumpet*, the last chamber being so shaped; the walls separating the chambers are simple in their construction, and the genus is classed lower than the Nautilus.

It is said that Walsall, situated on the same line of rocks, but some miles distant, affords a better field for bivalves, though Benthal stands pre-eminent for corals.

For the most curious and characteristic of Silurian fossils, we should need to visit Dudley, that being the best field for crustaceans. There Trilobites are the prevailing fossil, though mingled with corals, encrinites, and abundance of stone-lilies. The Trilobite is

PLATE II.—DEVONIAN.

1. Holoptychius. 2. Coccosteus. 3. Pterichthys. 4. Cephalaspis. 5. Osteolepis. 6, 7. Madrepores.

so named because of the three ridges which mark its body. Its head is defended by a crescent-shaped shield, its body by plated armour, in the style of our familiar shrimp, and the tail has a similar defence. The eyes are its most remarkable feature, cone-shaped and consisting of numerous lenses, enabling the creature to see before and behind, above and below. They are constructed on the same principle as those of the dragon-fly. The animal floated in the water, back downward, fed on animalculæ, and probably burrowed in the mud. They occur in great numbers, ten genera being found in England, seventy-one in Scandinavia, and twenty-seven in Bohemia, according to M. Barranda (Pl. 1, fig. 3).

The most recent of the Silurian rocks are well exposed at Ludlow, and take their name from that place. Visiting that interesting neighbourhood with Mr. Wood, we had the advantage of the guidance of that eminent local geologist, Mr. Lightbody. In his company we explored the beautiful series of rocks which follow the course of the river, and which exhibit first the Lower Ludlow, then the Aymestry, and beyond the Upper Ludlow strata.

A most picturesque quarryman, with grisly beard, and of the stature of a giant, was breaking the stone in search of fossils in the Lower Ludlow cutting. A few pence readily won him to our interests, and he was soon diligently engaged with

pick and lever to find the desired booty. The back of the quarry presented the appearance of an unbroken wall; at one corner a portion, as of an inner wall, equally even and entire, remained, showing that it was the nature of the rock to split into perpendicular sheets. Mr. Lightbody excavated a Lingula, while we watched the quarryman's efforts; and we then proceeded to the Aymestry rocks. Here the hammers of my two companions soon separated pieces of stone from the parent rock, in which the finely-striated shells of the brachiopod Strophomena, were abundantly exhibited. Another brachiopod, called Pentamerus, is frequently found in this formation. Mr. Lightbody had several in his collection. Their upper valves are much inflated, and the beak bends over like that of a parrot; they are grooved lengthways, and striated across. A piece of iron-tinted stone contained numerous casts of this shell; at first sight they reminded me of Brazil nuts imbedded in clay (Pl. 1, fig. 8).

Mr. Lightbody had beautiful Graptolites from this Aymestry rock. They appear as white marks upon the slabs of dark blue stone. The clear delineation of the white outline rivals the most careful drawing. There are several varieties—one of about an inch in length, and resembling a miniature saw, lies in great numbers on a slab no bigger than a man's hand; another and scarcer species is curved, while exquisitely branched tracery

in brown, upon a lighter stone, resembling our recent Sertularia, is pronounced to be a branched Graptolite. Star-fishes, too, grace these rocks, and the Lower Ludlow ones; indeed one has been found in the Wenlock shale, and minute Crinoids are occasionally found, perfect in structure as those of later date, though but attaining the height of a few inches. Our crippled giant brought us Orthoceratites, a Crinoid, and shells of Spirifer, and Terebratula, in gratitude for the "pence" past and to come. We found beautiful blocks of Lower Ludlow rock piled in the quarries, their surface thickly strewn with small brachiopods, as Rhynconella and Chonites, or variegated with light-coloured blotches, indicating worm tracks. Above these quarries lies the table-land where Cromwell placed his artillery when he destroyed the fair proportions of Ludlow Castle. The ruined towers now clothe the summit of the rock on the opposite side of the river, and look as old to the uninstructed eye as the exposed strata of stone which crop out here and there beneath its foundations. Yet what an infinitely greater antiquity do the rocks denote!

Mr. Lightbody showed us good remains of Trilobites from the Aymestry rocks, and numerous fragmentary fossils, as fish remains, and shell markings, from the "passage beds," exposed by the railway cutting near the station. These "passage beds" lie on the summit of the Silurian system, and mark the transition into the Old Red

Sandstone. The stone varies in colour, and breaks into plates, some resembling sandy slate. The fossils are too rudimentary to be beautiful, but it is instructive to see indications of the inhabitants of this geological border land.

Considerable modifications occur in Silurian rocks; in some places clays have been converted into slate, and these are quarried for roofing, though by no means equal to those of the clay-slate. We also find limestone converted into marble, and sand into quartz. In crevices filled with quartz metallic veins occasionally occur, with sulphurets containing a little gold. These are now worked in Wales.

One or two fishes have been descried in the uppermost members of the Silurian system, and frequent markings of seaweeds. The fishes, however, may be regarded rather as the dawn of the Old Red than actually belonging to the Silurian; and Corals, Encrinites, Trilobites, Brachiopods, and Algæ remain the characteristic fossils of this unvarying Oceanic period.

CHAPTER III.

DEVONIAN SYSTEM.

"What sea, receding from what former world,
Consigned these tribes to stony sepulchres?
Bewildered sage, proclaim thy wisdom folly,
And where thy reason fails let faith begin.
The rocks have sacred secrets of their own,
And teach the wise humility and praise."

DR. ANDERSON.

THE waters of the ocean still cover the space now occupied by the British Isles, and in their angry waves the broken rocks are rolled and ground into pebbles; thus over wide areas a coarse conglomerate of sands and stones is deposited, the former coloured with a lighter or darker shade of red by oxide of iron, held in solution by these stormy waters. A more peaceful time follows when beds of sand or mud are deposited here and there, forming the burial-places of crab-like creatures and shell-fish. Shallows ensue, and gradually dry land

and streams of fresh water appear. Thus, succeeding the Silurian strata in geological order, though often placed side by side with it in deposition, we have the extensive system characterized as the Old Red Sandstone or Devonian.

The districts where these rocks rise to the surface in the present day have considerable charm of scenery. Parts of Shropshire, Hereford, and South Wales offer a pure type of its effect; rounded and well-wooded hills, undulating fields, and valleys traversed by goodly streams. On the shores of Scotland we have it in grander development, raised upon the shoulders of uplifted masses of granite and gneiss, and forming a noble line of defence against the advancing waves of the sea; it occasionally juts out in detached pinnacles or pillars beyond the coast-line, both on the shore of Scotland in Aberdeenshire, and on that of Devon. The rich tint of the rocks adds greatly to their picturesque effect, whether contrasted with the blue expanse of ocean, or the verdant woods and pastures of the softer scenery. Mosses take kindly to the sandstone, and we frequently find the glowing colour of the rock toned down by the most artistic contrasts of Nature's own painting.

The lower members of the Old Red Sandstone series were supposed, until recently, to be very poor in fossils; when, as Mr. Roberts says, "the Scotch stone-cutter found armour-clad fishes in the stone he worked, and wrote of them in language

quaint as their forms and glowing as the glitter of their scales. He lit up the darkest courts of the temple, and, entering it, we wondered no less at the weird forms embedded in the walls, than at the graphic tales he had told us of them." He, afterwards *the great* Hugh Miller, going to work as a raw "laddie," began at once closely to observe all markings in the rocks. After a while his trade called him to Cromarty, and his first holiday was spent in a more carefully prosecuted examination of the conglomerate beds on and about the coast.

On laying open a piece of light-coloured limestone, with a blow of his hammer, he found the "effigy of a creature," cast, apparently in jet: the body resembled a small turtle, the head being all one with the trunk, and from it proceeded two wing-like arms; the eyes were close together, and fixed upon prominences. This fossil being submitted to Agassiz, he pronounced it to be a fish, but of a type greatly differing from any existing, and which Agassiz had only recently become aware had ever existed. He explained that the wing-like arms were weapons of defence, which, like the species of the river bull-head, were erected when attacked by an enemy. Prosecuting his search, the scientific stonemason found great numbers of these forms, occupying, with others, beds situated upon or intermingling with the great conglomerate. Nine-tenths of the speci-

mens were found with the paddles erected, and thus, he says, "we read in the stone a singularly preserved story of the instinctive love of life; and of the mingled fear and anger implanted for its preservation. It presents us, too, with a wonderful record, of violent death falling at once, not on a few individuals, but on whole tribes."

Hugh Miller compares this winged fish (*Pterichthys*) (Pl. 2, fig. 3), to the rudely-drawn figure of a man, the head cut off by the shoulders, the arms spread, the body narrowing from the chest downwards, with one leg only, and that placed in the centre of the figure. Its size was but a few inches, and it was covered with strongly enamelled scales on the upper part, the lower part probably, by tough scales also.

All fishes of the present day may be divided into two classes, those that have bony and those that have muscle-like skeletons. The shark is a specimen of the latter class; its skeleton will decay in a fortnight, while the minutest part of the skeleton of a bony fish remains perfect in the rock. We cannot define one as a lower and the other as a higher organization; they appear on ocean's stage and are carried forward together. As Professor Owen so vigorously explains, "the various structures of animal frames were originally impressed upon them at their creation, and have neither been derived from improvement of a lower, nor lost by progressive development of a

higher type." Certain it is that the lower races of plants and animals were first introduced into our world, corals, radiates, molluscs and articulates, along with ferns, in the Silurian; now fishes and higher cryptogams, and presently reptiles, birds and palms, etc. But among them all there was no failing attempt, no rejected essay; each was wonderfully and marvellously made, and exactly adapted to the position and the action for which it was designed. The fishes of the Old Red Sandstone hold an intermediate place between the bony and muscular classes, and on this account some part is wanting in all their fossil remains. The jaws are found, the scales lie perfect in their proper place, the bones of the skull and shoulder are well preserved, and also the bony rays of the fins, whilst the vertebral column is wanting altogether. On the other hand, in fossils of bony fish, it is the skeletons which are alone preserved; no scale remains. All these curious fishes of the Old Red Sandstone, half bony, and half muscular, belong to the order of which the *shining scale* is the grand characteristic (*Ganoid*). Here the scales glitter with enamel, and those found in the same formation in the cornstone of Worcestershire are described as resembling morsels of tortoise shell. Most of the cartilaginous fishes of the present day belong to the *broad scale* order *(Placoids);* a third order is characterized by comb-like scales (*Ctenoids*); while scales with *simple*

margin (*Cycloids*) mark the fourth class. Our friend the winged fish is a *Ganoid*, as are also others which I shall proceed to describe from the observations of Hugh Miller.

He compares the figure of Coccosteus (Pl. 2, fig. 2), to a boy's kite; the plates of the head are arranged with architectural elegance, and a single plate covers great part of the body, rising in the style of a saddle towards the centre. The teeth are cut out of the solid jaw, like the mandibles of a beetle or the nippers of a lobster, and the jaws are vertical! He describes five species of Coccosteus and as many of Pterichthys.

At Caithness several species of a handsome fish called Osteolepis were found (Pl. 2, fig. 5). In this fish the jaws and teeth are naked, and the bone beautifully enamelled. From this, and from the bony nature of its scales, it got the name of bone-fish; the rays and points of the fins were enamelled also; indeed "all was bone without, all cartilage within; it was cased in complete armour; the head in plated mail, the body in scaly mail; fins a mail of bars and joints, and all exquisitely punctured." Similar in structure were the Dipterus and Diploterus, ganoid fishes furnished with double wings; the burnished plates covering the head gives them the appearance of helmets.

The scales of the Glytolepis (*carved-scale*) were beautifully sculptured and enamelled, and formed ridges drooping down from the head and

body. Those of the elegant Cheirolepis were so fretted by grooves and ridges, and so highly polished, that they resembled "a little bunch of thorns varnished with ice."

In all these fishes the bony rays of the fins, thin and branching, were connected but not covered by a membrane. Hugh Miller calls them bird-wing fins, the rays representing the regularly placed feathers. Another group of fishes are found in the same rocks, which he denominates bat-wing finned; and here one spear-like ray stands out as a mast, and a sail-like membrane stretching from it forms the fin.

The Cheiracanthus or Thorny-hand, a slender tapering little fish with unequally-lobed tail, belongs to this bat-wing group. The silvery fins are dotted with minute scales, the body scales fretted with parallel etchings. And this brings forward another peculiarity in these early fishes, that instead of their tails being equally lobed, as in the fish of the present day, one of the lobes only was fully developed, while the other was merely rudimentary.

The beauty of the structure of these fossil fish can only be demonstrated by microscopic examination; their mail-armour perfect in every joint and groove, their polished helmets and curiously contrived breast-plates, "appropriate ornaments to be set in gold for a lady," as Dr. Buckland said, were all marvellous in beauty.

Here and there about Cromarty these and other fishes were found, and also in Caithness, where they were accompanied by shells, frequent in the same formation in Herefordshire; as in the Herefordshire Old Red numerous fragments of the Caithness fishes are likewise found. Occasional markings indicate the remains of Algæ and Stigmaria. Some of the Cromarty beds were covered by lias stone, others by recent deposits, and others again by the Trias rocks. In Caithness the animal remains are so replete with bitumen that they burn readily. At Gowrie the nodules containing fossils have a somewhat crystalline structure, giving them a resemblance to asbestos.

In the same formation in the S.W. of England as we saw in Fifeshire, the Pterygotus is found; from a likeness of form it has received the name of "Father of all Shrimps;"—it is several feet in length. A few Trilobites still remain, and some Brachiopods and chambered shells occur; though a larger number characterize the cornstones.

In the cornstone of Herefordshire, Shropshire, and Monmouthshire, four different species of the buckler-headed fish (*Cephalaspis*) (Pl. 2, fig. 4), are found. The shape has been compared to that of a saddler's knife, the crescent-like blade its head, the handle, somewhat widened, its body. The head occupies a third part of the animal's length; its eyes are close together, and its thin body has a jointed appearance, its covering of bony scales

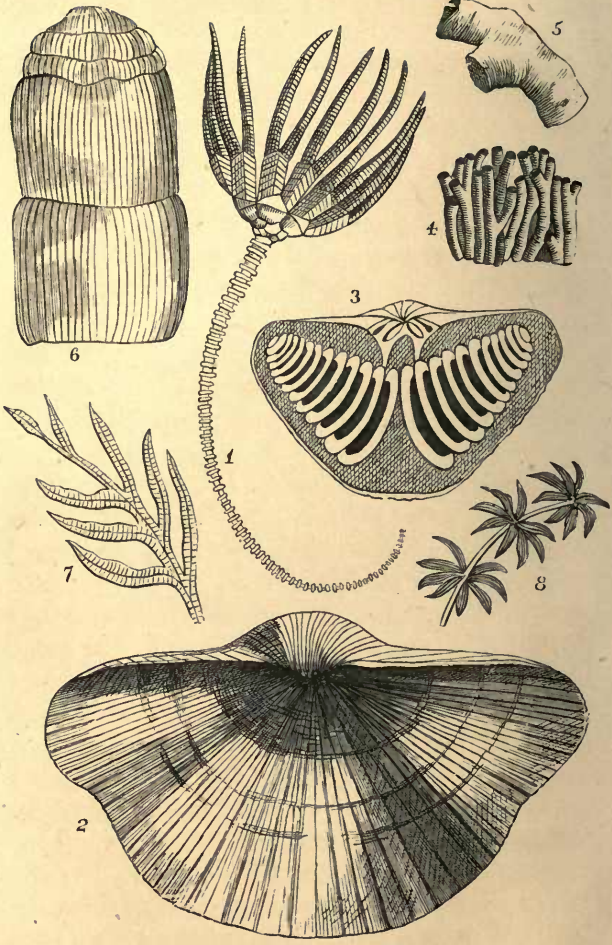


PLATE III.—CARBONIFEROUS.

1. Crinoid. 2. Giant Productus. 3. Spirifer, with arms.
5. Corals. 6, 7, 8. Coal Plants.

giving it a resemblance to a lobster or trilobite. The buckler-like covering of the head and the scales are so enduring that they are preserved in rocks impregnated with iron, generally so destructive to organic remains. Agassiz suggested that the pointed horns of the head were given as weapons of defence. This fish is "a medal of the middle empire," not occurring in the lower members of the Old Red but found in the gray sand of Forfar and the cornstone of England. In Fife this stratum has only vegetable remains, "darkened impressions of stems, leaflets drawn in black, and circular forms supposed to be seed vessels."

At Balruddery both scales of Cephalaspis and vegetable remains are found in this stratum, also a fossil lobster of large dimensions, with sculptured shell. This Balruddery stone is of a blueish-grey colour. The Cephalaspis and lobster are here. Roberts states that seeds as large as peas, probably those of Lycopods, are found in the Old Red of Wales; these are probably similar to those described by Hugh Miller in the gray sand of Fife.

In Devonshire and Cornwall there is a series of fossiliferous limestone, and grits or shales containing corals in great quantity, so that the "Devonshire marble" is almost entirely formed of them. We have here again the Cyathophyllum, Favosites, and Heliolites of the Silurian, with other allied corals of new species. These form the "Madre-

pore pebbles" (Pl. 2, figs. 6, 7), which visitors on the coast of Devon seek so eagerly. I remember we called the Cup-coral a "fossil limpet," and were quite sure the Heliotes was a sponge. These are washed from the limestone rocks, and when thoroughly rolled and waterworn are thrown upon the beach along with old corks, broken bottles, and periwinkle shells; when wet with the sea-water the stone is semi-transparent, and the organism is very perceptible.

These rocks belong to the middle division of the Old Red series, as do also the shale cliffs on the South East coast of Cornwall, from whence Mr. Pengelly has procured many fossils. I have spent many an hour hammering for them in vain; one or two was all the reward that ever crowned my industry.

Above the cornstone and gray sand we find a layer of variegated stone, sometimes red, but generally red and green and grey, and over that a stratum of lime and yellow sandstone.

In England this is known as the quartzose conglomerate; there it is very barren of fossils. Murchison detected one scale of Holoptychius in it; but in Scotland and in Russia it is highly fossiliferous. Holoptychius is the prevailing fossil, a noble fish whose teeth are from one to three inches long, covered with massive plates, elliptical in form, brilliant with glossy enamel above and porous beneath,—these ivory scales have tubercles

within the margin: the head small and covered with bony plates, the fins thick at the base, and spreading like the rays of a circle (Pl. 2, fig. 1). Some specimens measure two and a half feet in length, and two feet in breath. The jaws are solid, and japanned like those of Osteolepis, and adorned with tubercles on the outside. In no place is this fossil so abundant as at Dura Den, in Fife, where every slab in one part of the quarry is crowded with its remains. As many as thirty fishes were counted upon one slab. This yellow sandstone of Dura Den is soft and easily wrought when first lifted, but hardens quickly on exposure to the air. Scales and other remains are found all through, but in one layer the entire fishes lie in abundance, and these being of a bright deep black, afford a striking contrast to the pale stone. Species of Glyptolepis and one of Pterichthys are associated with Holoptychius here. The Torquay beds are of the same date as these yellow sands of Fife.

Thus in the second period of animal life we have repetitions of the old forms, though some have already died out. Corals as numerous as in the Silurian age;—crinoids still wave in the seas, and are associated with molluscs and crustaceans. Traces of sea-weed are abundant, and the remains of a few land plants, allied to the ferns and lycopods, mark an advance in vegetation. But all these fossils are very local, occurring in numbers in one

place, and absent in other developments of the same member of the formation. The immense accumulation of worn pebbles from the older rocks suggests a stormy ocean, and probably a glacial one, in which the curious ganoid fishes lived and sported; possibly it was when overtaken by a change of climate that they erected their defensive weapons and died in myriads!

Extensive as this formation is, it is not productive of many useful materials. The Carmylie stone is tough, owing to the abundance of mica entering into its composition; it is used locally for roofing, lining cisterns, and paving streets. In Fifeshire this stone is quarried for building purposes. In the counties where the freestones occur, whether in England or Scotland, they are used for building, and though an architect would laugh you to scorn did you suggest their selecting Old Red Sandstone for a church or public building, yet few can withhold their admiration from the warm hue and weather staining of the quaint churches built by our forefathers of this material. Devonshire marble is good and useful as an ornamental stone. In the traps piercing the Old Red, or in the sandstone metamorphosed by them, we find jaspar, cornelian, and chalcedony.

CHAPTER IV.

CARBONIFEROUS SYSTEM.

MOUNTAIN LIMESTONE.—MILLSTONE GRIT.—COAL MEASURES.

"It is a lonely place, and at the side
Rises a mountain rock in rugged pride;
And in that rock are shapes of shells, and forms
Of creatures in old worlds, and nameless worms.
Whole generations lived and died, ere man,
A worm of other class, to crawl began."

CRABBE.

A MORE peaceful ocean now seems to favour our globe, depositing quietly accumulated sands and muds upon the storm-tossed wrecks of the Devonian rocks; and from the patiently won waste of the older formations, deriving strata which present every variety of composition. Now we meet with sandstones, ranging from pure white quartz to mere shales or slaty flags,—while the limestones vary from pure white marble to dark grits. The iron is no longer diffused through the

whole mass, giving its hue to the rock, but is deposited in layers of ironstone; coral reefs abound, rising into islands among the shallows, and presently clothed with luxuriant vegetation. Upon land already formed, ferns and cycad allies flourish abundantly, while the river delta abounds with fresh-water mussels and univalves, and is infested with small frog-like reptiles, tyrannized over by a few Saurians. During this state of things, periods of volcanic disturbances occurred, and finally the wide stretches of forest forming the coal measures sunk gradually beneath the waters.

The Lower coal measures, otherwise known as Carboniferous slates, repose upon the Old Red Sandstone, but are wanting in very many parts where the other members of the formation occur. They are well developed in Nova Scotia and in Ireland; and in the neighbourhood of Edinburgh, and in Fifeshire, the stratum is valuable and interesting; producing the fine white sandstone quarried on the Frith of Forth, and furnishing nearly all the buildings of Edinburgh; and further, as presenting in the fossils of Burdie House a rich variety of Wedge and Comb ferns (*Sphenopteris* and *Pecopteris*), Calamites, plants of the structure of the Equisetum, and Lepidodendron, a gigantic ally of the Club-mosses; a number of estuary shells, and a few reptiles. Professor Huxley detected two varieties of Labyrinthodon in the

Burdie House limestone, so called from the labyrinthine construction of their teeth. These reptiles are furnished with legs, and are covered with scales like fishes; they have huge jaws, fourteen inches long. One of these Labyrinthodons measured forty-three inches. These are connected with the ganoid fishes of the Old Red, through the Shining-headed Saurian (*Ganocephala*), one species of which is also found at Burdie House. The Archegosaurus, and the Saurian fish, Holoptychius, are present in marine bands of the estuary limestone of Burntisland, where some other fish remains are also detected.

The mountain limestone, the coral reefs of that ancient sea, presents a group of rocks interesting alike to the artist and the naturalist. It often forms mountain ranges, with elevated peaks as in Westmoreland, Derbyshire, and Yorkshire, but it is more often found flanking the igneous rocks, when it forms bold escarpments facing one another at some distance, while the interval is occupied by rocks of lower elevation. Its colour varies to all tints of blue and grey, and it is found occasionally reddened by iron as in Somersetshire, or blackened by carbon. In the districts of the mountain limestone, we have bold cliffs called Scars, as at Malham Cove, Llangollen, Matlock, Cheddar, and Clifton; and splendid waterfalls, as in the North of Yorkshire, and in

Durham. The mossy verdure that creeps around and half clothes the gray rock, has its own charm; and as you descend into the dales, the eye is enchanted with the rich verdure of the pastures, the thick and rounded woods, and the streams foaming over their rocky beds.

A striking feature in this group of rocks is the dislocation apparently natural to the stone, and which, admitting the water, causes, in the lapse of ages, caverns of enormous size and complex form. The drainage of the valley of the Greta passes through subterranean passages thus formed. In one of the principal caverns, Wethercote, there is a subterranean waterfall twenty-five feet high, over which a huge mass of rock is suspended. Ingleborough is undermined by strings of caverns. Only the entrance, or, so to speak, the porch, of the one called *par excellence* Ingleborough cave, was known until of late years, a mass of stalagmite having filled up the passage beyond. This stalagmite is a constant agent in these caves, or, more properly, an effect of a constant agent. The water filtering through the rock, charged with carbonic acid, acts upon the lime, which it deposits either in icicle-like pendants, called Stalactites, or in raised mounds on the ground, Stalagmites. It occurred to a working man one day to break down this accumulation of stalagmite, and thus a passage was laid open, and access was obtained to a series of caverns and passages winding in a northerly

direction, till a magnificent grotto was reached, richly adorned with stalactites. The explorers heard water falling in the dark distance beyond, but this did not stop their research. Cautiously pursuing their way they came to a deep pool or linn, round which Mr. James Farrer had the hardihood to swim, with a candle fastened in his cap, and a rope round his body. This was the limit of their subterranean exploration. On examining the country on the exterior, it was found that a stream disappeared down a fissure in the rock, and this doubtless caused the subterranean waterfall and pool. Professor Phillips gives a full account of this cave and some others in his "Geology of Yorkshire." Mr. Williams, of Farlow, relates an interesting fact of the discovery of a subterranean stream, the "Mole river," in one of the Oreton quarries, Shropshire.

Rich veins of metals—lead, zinc, and antimony—are found in this rock, and the hills are everywhere pierced with mines—some having existed since before the invasion of the Saxons. The ironstone occurs in bands, or in nodules cropping out from the rocks.

The lower stratum of the Carboniferous Limestone, the millstone grit, so called because used for millstones, is often one thousand feet thick. It is a hard, coarse stone. On very rare occasions vegetable remains have been found in it, as at Blorenge, but it is a rock very poor in fossils; it is

well exposed at Healaugh in Swaledale, North Yorkshire.

Within a short distance of this millstone crag rises a hill, called Calver, according to the genius of the country; and from hence, on either side the valley, the true mountain limestone is continuously exposed, and its numerous fossils rise to the light of day. The loose walls, built of slabs of this stone, are often mere masses of encrinital stems, while the "cockle bed" appears in every carelessly worked quarry, the myriads of brachiopods giving a shell-like cleavage to the stone. Mr. Wood, of Richmond, has been most successful in disinterring the crinoids. New and beautiful forms of these animal lilies have been brought by him to the light, and not only his own beautiful collection and those of his private friends have been enriched with these trophies won from nature, but the public museums have benefited by his labour (Pl. 3, fig. 1). The beautiful waterfall, called Keasdon Force, pours over rocks formed of encrinites and brachiopods; indeed, these fossils characterize every rock in the neighbourhood. *Productus Giganteus* (Pl. 3, fig. 2), is the most important of these brachiopods, both in size and numbers; it is a massive shell, seven or eight inches across, doubly ribbed, and with wing-like projections on either side the overlapping hinge. In Somersetshire and Herefordshire, as well as in Yorkshire, I have found it in great abundance;

in fact, it is so prevailing a fossil that the formation is sometimes called from it "Productus-bed;" its name, meaning *prolonged*, is because of the upper valve being prolonged over the under. There are many species of Productus, all bearing a resemblance to this, but none equalling it in size. In the same quarries are found various Spirifers (Pl. 3, fig. 3), so called as having the spiral organs very fully developed. These shells are broader than long, both valves inflated, and very broad and straight at the hinge side. Terebratula is a genus of brachiopods frequent in this stratum; its name means *pierced*, in allusion to the hole at the hinge apex, where the fibres were passed through; these shells are ribbed in some species, circularly foliated in others, and at times plain. The Rhynconella (*little beak*, from the acute beak at its hinge), is a genus smaller in size, but important enough in the number of its members. The shell is somewhat triangular, the sides being rather curved; it is generally ribbed; the under valve is raised in front and hollowed at the sides, the upper depressed in front and raised at the sides; so that this valve appears to have two lateral ridges, and but one central ridge. Only two or three living species are known, while, counting the fossil ones, from the Silurian upwards, a number exceeding two hundred is reached! Inoceramus shells, of the oyster family, are occasionally found; they have a rudimentary wing on

the left side—the other is rounded; they are longitudinally grooved; members also of the mussel family are not uncommon. The "Cockle-bed" of Swaledale furnishes a coiled univalve of the Turban family, called Euomphalus, varying in size from the circumference of a shilling to twelve inches.

Chambered shells also are present there—several specimens of Orthoceratites rewarded our search, and the Bellerophon is found elsewhere in the formation. This is of the Nautilus family, the shell consisting in a single chamber. The corals (Pl. 3, figs. 4 and 5), of the system are abundant both in number and size. As you wander by the mountain brooks, traversing every ravine, you see masses several tons in weight, formed entirely of the simple tubes of the Polypora, (many-pore), Retopora (net-pore), or Vincularia (chain-pore) Scales and teeth of fishes have frequently been found by Mr. Wood: Psammodus (sand-tooth), Orodus (beautiful tooth), and Helodus (stud-tooth). These were also found by Mr. Roberts, along with chain and other coral, and brachiopods, in the mountain limestone of the Forest of Dean.

Remains of several Chitons have been discovered in this rock, in the neighbourhood of Settle, by Mr. Burrow. He describes the locality of the Scar as "a field within a hundred yards of a very beautiful little waterfall, called Scaleber Fell."

On the opposite side of Swaledale to the "Cockle-beds" we came to a quarry of slaty sandstone, upon almost every slab of which were raised marks, some resembling small fossil eels, coiled in various ways, and others not larger than worms. These perplexed us considerably; there was no trace of an organism, only an elevation in the sandstone. Mr. Wood had also been puzzled by these markings, and had sent some of them to Professor E. Forbes, who had abelled them "Casts of Annelid Tubes;" but it rested with Hancock to supply a direct clue to the mystery. While walking on the sea-shore on the coast of Ayr, and afterwards of Durham, he observed similar raised mounds of considerable length and varying form, some with grooves, some with nodular enlargements at equal distances. He watched as the tide receded, and at last found one of the mounds in process of formation. Every few minutes the sand was a little agitated, and thus about half an inch was added to the track. When he had watched some time he suddenly took up the sand at the point of the track, and captured a small crustacean. He then watched a track of a different form, and took the workman prisoner; and putting both into a vessel of sand wet with sea water, he watched them again forming their characteristic tracks; one of them seemed to have a trick of hunching itself up at intervals, so that its track had nodular enlarge-

ments. Our Swaledale tracks were like some fossil ones, from the same formation which he describes. One had a ridge on either side, the second was smooth and circular, and a third had a groove along the middle. Mr. Wood considers this sandstone bed to be equivalent to the flagstones described by Professor Phillips as "laminated rock, composed of small worn grains of quartz and mica, with or without felspar; occasionally calcareous, arenaceous, or argillaceous."

"The tops and bottoms of gritstone rocks," says Hancock, "are often thus laminated; the plates becoming very sandy, turn to flagstone." He explains that when these tracks cross one another they cut through the opposing track, thus showing themselves not to be Annelid tubes, which must have lain over each other. They are probably tracks of Trilobites, several species of which occur in the associated beds. He concludes, "Numerous Trilobites might have existed during the deposition of these flagstones, and have perished with the other inhabitants of these seas, leaving no trace except these footprints in the sand. Such footprints are all that is left in the world's stony records of many existences that have passed away; and so it may be with these fossil tracks." The Trilobites correspond well to the size of the tracks.

We now come to the Coal formation, a deposit of the greatest importance and interest, for to it

we owe much of our national prosperity. The value of gold is but as a feather's weight compared to the coal and its accompanying iron. Coal is formed entirely of the remains of plants—mostly ferns—not the small species found in our hedge-banks, but ferns of gigantic size, such as form the trees in the fern valleys of New Zealand at the present day; but all of so soft and succulent a nature, without woody fibre, that they could be squeezed up and decomposed into one solid mass. Such trees, forming forests, with a jungle-like undergrowth, vapour charged with carbonic acid gas steaming around, forced on vegetable growth into unnaturally rapid increase and premature decay, while no highly organized thing could exist in the unwholesome air. The sun never shone through this thick atmosphere, which must have been of the density of a London fog. Succulent plants, weakened by excessive development of their juices, suggest this to have been the state of things, and seedless ferns that grew on till they rivalled forest trees in stature, confirm it. These rose to forty, sixty, and even one hundred feet in height, colossal and beautiful, some representing Nature's first design of column and capital, with their stately boles and crown of plume-like fronds, others all stern and hairy, clustering and interlacing in prodigality of verdure. All was green—no flowers—none, at any rate, abundant enough to affect the general aspect.

A few fresh-water mussels lived in the brackish water, varying with bands of estuary deposit the generally vegetable formation.

By the down-sinking of the land this teeming forest became submerged; then carbonates and oxides, held in solution by the water, acted upon the sunken masses, earthy matter was deposited upon it, "until all evidence of its former state was hidden beneath an iron-tinged sediment; thus both the coal and its iron bands were formed." Besides the ferns, which form the greater part of the fossils of this formation, we have Stigmaria and Sigillaria; the one now decided to be the root and the other the stem of a tree, pronounced by M. Brogniart to be of the two-lobed class. "They were tall, erect trees, with a regular and cylindrical stem," he says, "without side branches, but forked towards the summit. Their superficial bark was hard and durable, channeled longitudinally, bearing leaf scars of a rounded form above and below, and angular at the sides, often oblong in relation to the stem. Their foliage consists of long linear leaves." Lepidodendrons, too, were there of all sizes, from mere twigs to trunks fifty feet in length. The leaf-scars are like scales, and the name means a *scale tree*. Professor Lindley places the Lepidodendron between the Lycopods and the Conifers, but M. Brogniart and Dr. Hooker regard it as a gigantic club moss, Lepidophyllum being the leaf, and

Lepidostrobus the fruit. Starry leaves mingle with the other vegetation (Pl. 3, fig. 8), belonging to plants not yet fully understood; and Calamites (Pl. 3, fig. 6), of horse-tail similarity abound. Knorria is another class of plants found in the coal measures; their leaves were set densely in a spiral manner, and the leaf scars are raised instead of depressed as in Stigmaria.

Mr. Symonds relates that Sir C. Lyell and Mr. Dawson procured portions of the skeleton of a reptile from the interior of an erect Sigillaria, which grew on the ancient land of Nova Scotia. "The shell of an air-breathing mollusk, allied to pupa, had been washed into the hollow tree with the skeleton of the reptile. This is the oldest known land-shell, the first air-breathing mollusk yet discovered; and is interesting as associated with the earliest of known air-breathing reptiles. The reptile is named Dendrerpeton, Tree-Lizard, and is ranked by Professor Owen in the Ganocephalous order."

He mentions another reptile of the Batrachian, or Frog order, found in the coal of Ohio.

Perhaps some may imagine that the frog shown as found in the mass of coal at the recent International Exhibition, was a lineal descendant of these Batrachians, emanating from their fossil spawn! Such an hypothesis is not more unreasonable than the one very generally believed of "a live frog being found in a block of coal." Mr.

Buckland (the son of the famous Dr. Buckland), has taken great pains to explain how easily a young frog, a denizen of the stream close by the pit's mouth, might fall down through the opening, or descend with the miners, having hopped by accident into the lift; or he might, as Professor Owen says, "tumble down a pit's mouth, as scores of frogs do, when but a few grains in weight, and drop into one of the numerous pools of water without any bones being broken. Once down in the pit they crawl off into any dark fissure."

Page truly reports "the remains of insects allied to the cockroach, beetle, and grasshopper," in this formation, but no live frogs.

This Carboniferous system occupies a considerable area in the British Isles, as well as in Germany, Belgium, and Nova Scotia. It is calculated that more coal is raised in Britain, yearly, than in all the rest of the world; and should the demand for it increase in the ratio it has done of late, a couple more centuries will exhaust the beds. Even should this be the case, we must then import it, or find a substitute.

"There are those who ask in unbelieving dread, for how few years to come
Will the black cellars of the earth supply to him fuel for his winter?
Fear not, O man! for thyself nor for thy seed; with a multitude is plenty.
God's blessing giveth increase, and with it larger than enough."

The rocks of this system are fully developed in the centre of Scotland, and the North and North-West of England, extending through Lancashire, Derbyshire, and Staffordshire, keeping up a line of connection by Shropshire, Worcestershire, and the Forest of Dean, reappearing in full force in Wales, and again across the Bristol Channel in Somersetshire and Devonshire. The line is almost due North and South, though bearing somewhat to the West.

Here we have the first-formed fossils dying out; Trilobites scarce, Corals and Encrinites in large development; fishes continuous, and the Vertebratæ next in importance, the reptiles, appearing; the Brachiopods, Gasteropods, and Cephalopods bearing on evenly; and insects just coming on the stage. But the characteristic fossils of the formation are undoubtedly the Ferns and Arborescent plants, Lycopods and Calamites. These never appear again in anything like the same abundance.

CHAPTER V.

PERMIAN SYSTEM.

"To read the antique history of earth, stamped upon those medals in the rock
Which Design hath rescued from decay, to tell of the green infancy of Time:
To gather from the unconsidered shingle mottled star-like agates,
Full of unstoried flowers in the budding bloom chalcedony.
Or gay and curious shells, fretted with microscopic carving,
Coralline, and fresh sea-weed, spreading forth their delicate branches." MARTIN TUPPER.

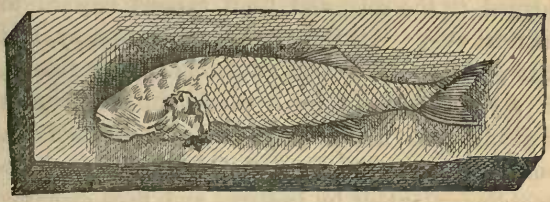
AFTER the deposition of the coal-measures, it appears that by an elevation of sea-level and other disturbing influences, a quantity of coarse gravel, to all appearance the waste of granite and other rocks, was deposited over limited areas. Sometimes these beds lie in regularity over the coal formation, but often the coal is tilted up beneath them, and they lie in hollows or around its shoulders. The latter is the case in the Permian deposits of the South of Yorkshire, while the former condition prevails near Bristol, and in that large district of Permia in Russia, from whence

this system takes its name. These pebbly conglomerates are accompanied by reddish sand and limestones, and form the first member of the system, Laminated Limestone. Beds of Gypseus Marl come next; then the Magnesian Limestone; Marl Slates; and, finally, the Lower Red Sandstone is included in the Permian group as partaking in the nature of its fossils of the ancient rather than the middle type of life. The Permian rocks are well developed in Durham, and extend in a thin band across that county, Yorkshire, and Derbyshire. They reappear in a very rudimentary form about Bristol, and in Cheshire. In Russia, they occupy a vast basin thrice the size of the kingdom of France. The soft marls and friable sandstones of this period are easily hollowed by watercourses, and thus a succession of gentle slopes and rounded elevations is produced, offering a pleasing and softened style of landscape. In this system the fossils are far less abundant than in the more important ones which preceded it; but we have still a considerable number of species, and an advance in the order of creation. In a quarry near Darlington, which Mr. Wood has had worked, many plants, corals, and fishes have been found. The quarry is of fine limestone, and is worked extensively for lime, and here numerous brachiopods, closely related to those of the Carboniferous Limestone, are found, with bivalves as Pecten, and univalves as Natica and Nautilus.

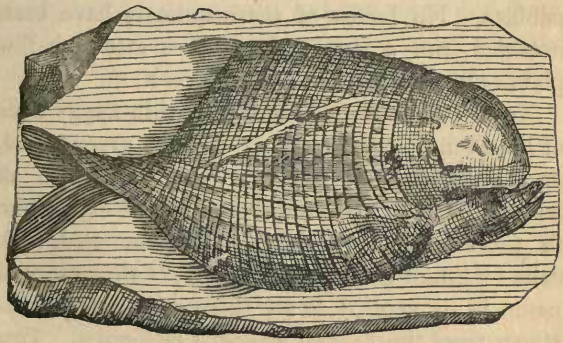
The Corals resemble those of the preceding formation. Below one stratum of limestone, and above another, is a layer of Marl-slate, a highly fossiliferous bed. This stone is useless for building or lime burning, and is only disturbed when a road has to be cut, or a railway cutting carried through it. In this bed Mr. Wood has had workmen employed from time to time, on purpose for the fossils, chiefly fish and plants. Two species of ganoid fish (*Palæoniscus*) have been found in considerable numbers—some of the remains very perfect. They are fishes of moderate size, with one-lobed tails, beautifully enamelled lozenge-shaped scales, and brush teeth. Another ganoid fish (*Platysomus*) there occurring is of a broad figure, and covered with large square scales arranged in sloping rows. Its teeth are thick, and disposed all over the palate, thus verging towards the middle-age type of ganoid rather than the ancient age. It is a large and fine species. Another fish, characteristic of the Marl-slate, and found in this quarry, is allied to our old Devonian friend the Holoptychius; it is a Sauroid-fish (*Cœlacanthus*), the marked feature of the family being the hollow fin spines.

In this Midderidge quarry many fossil ferns have been found, partly the forms already familiar during the Carboniferous era, and partly new species. About St Bees, the Permian conglomerate is exposed, the Red Marls and Gypsum, and

then Magnesian Limestone, with bivalves of the Mussel and Oyster families; the whole is topped by the fine Red Sandstone which forms St. Bees' Head, and which reappears in patches in Cumberland and Dumfriesshire.



PALÆONISCUS.



PLATYSOMUS.

To this member of the system the famous rocks of Corncockle Muir belong, so glowingly described by Mr. Symonds: "A noble quarry of bright red sandstone, backed by a large wood of Scotch and Spruce fir. A moss stretching below, and the sun

shining bright on the quarried strata, which reveal the marching of ancient reptiles long since perished—is not this a sight for a geologist? In some instances it may be seen where the animal has lifted his foot, and the mud and sand have clogged to the sole, and been carried onward to the next step. All the tracks tend one way, and have never yet been seen returning." The quarry, he says, is overlaid by a considerable thickness of glacial drift, and the plane of the sandstone is polished, and striated, and furrowed to an extraordinary extent by icebergs and floes grinding along the surface with their burden of stones and pebbles. No bones of these animals have been detected, nor a single plate discovered. A few plants allied to Cycas mark this rock.

Near Doncaster we meet with thin flaggy beds of limestone, with bands of red and green marl, and after this we find an extensive series of whitish or yellowish limestone, rather crystalline in texture. This is what Professor Sedgwick calls "Small-grained Dolomite," the original name being applied to all these magnesian limestones from the French geologist Dolomieu. This rock seems void of fossils, but most valuable as a building stone, its pure colour and crystalline texture rendering it exceedingly beautiful for architectural purposes.

Stone of this kind, quarried in Leicestershire, is used for the Houses of Parliament. Varieties of the lower limestone are often formed of rounded

morsels like peas, hence called Pisolite. About Sunderland it is found in bunches of large nodules, resembling grapes. At Broadsworth masses occur, according to Kirkby, composed mainly of corals; at Pontefract the rock is somewhat cellular in structure; and then again it appears compact and arenaceous. Corals of familiar forms mark the Broadsworth rocks, Retepora, Thamniscus, &c. Brachiopods still occur, also a one-chambered shell, one Turbo, and some species of Gasteropods, Rissoa, Turritella, and Chemnitzia; Dentalium appears pretty frequently, and occasional plates of Chiton are found. The Sauroid fishes begin to die out; but the prevailing fishes of the Permian have still unequal tails—they are smaller in size, but still with enamelled scales. The Batrachian reptiles are on the increase in this formation, as are also those of the Lizard family—thus true air-breathing, land-inhabiting animals take the place of the fierce Sauroid fishes. Palœosaurus and Protorausaurus are those whose remains most frequently occur; the latter is of high development, and Professor Owen says, if it were alive at the present day, "it would take rank at the head of the Lacertian order."

We have every reason to suppose that volcanic agency was at work at the end of this era. Professor Ansted thus expresses his view of the matter: "It is difficult to express the complication of disturbance, and the amount of confusion that has been produced on the solid crust of the

globe, between the close of what we have called the first epoch, and the commencement of the second; and yet all this was done with a certain degree of order, and doubtless occupied a long period of time. Volcanic eruptions have taken place in some districts, and their effect is seen in torrents of ancient lava, heaps of erupted ashes, and rocks chemically changed by the intrusion of heated vapours charged with gases. In others, enormous cracks extending for many hundred yards, or even for miles together, may be traced in the more brittle rocks; and the rocks themselves have been burnt as in a furnace by the boiling mass of molten lava which has been poured from beneath into the fissures. Sometimes extensive tracts, where the rocks are thinner and tougher, exhibit these cracks in systems of hundreds parallel to one another; while here and there the intense fiery action from beneath has thrown up the surface into blisters and domes, which are often fractured at the top, and thus reveal the history of their elevation. Still more frequently, the irresistible subterranean force has snapped asunder the strata, as a violent blow would pierce through a few folds of paper, and one side of the broken bed has been lifted high in the air, while the other has sunk into a deep hollow beneath. And if, as happened occasionally, the force was not sufficiently energetic to break up in this way the whole group of underlying matter, it might yet effect a no less striking result, raising up the

strata upon a line or point, and producing a saddle-backed or a dome-like elevation, according to the circumstances of the case. It is not unlikely that much of the general contour of the high ground of England and Northern Europe was originally marked out during the frequent disturbances of this interval of violence."

Although this Permian system is by no means rich in fossils, yet as each series of rocks contains a few, slightly differing from, though in the main features harmonizing with, those of the Carboniferous and Devonian formations, the groups are valuable as completing the list of ancient or Palæozoic forms. So far the vertebræ of the fishes have continued to the end of the tail, and this upper lobe has been larger than the lower; equal tails begin to appear in the future formations, and unequal ones to die out. Trilobites have disappeared, as well as their successors, the Sauroid fishes. The Fuci of the Silurian and Devonian have been succeeded by the prolific land vegetables of the Carboniferous age, while the Permian boasts representatives of both classes. The greatest advance of this series is in reptiles; it being in this respect the dawn of the Secondary, as well as the close of the Primary. Palæozoic, or ancient forms end here, though many linger on into the next great stage of life, thus showing a decided division in the world's ages, while the exceptions prevent the drawing of an actual line.

CHAPTER VI.

TRIASSIC SYSTEM.

"Some traced the footsteps of Old Time
Long fossilized."

MASSY.

IN opening upon the second grand age of geological observation we find the primeval patterns registered in the rocks the same in kind, though with new modifications. No more Trilobites and Graptolites, like those of Siluria, greet our eye; no more fishes clothed in tortoise-shell like those of the Old Red; we look in vain for the Stigmaria of the coal measures; for the cup, net, chain, and other corals spread through those earlier systems; or for the Sauroid fishes of the Carboniferous waters. The Mesozoic or Middle Ages exhibit plants allied with ferns, cycads, pines, fishes with tails where the equally-lobed

type becomes more and more prevalent; reptiles of varied size and power; birds, and even mammals. Page expresses the contrast of forms between the ancient and middle ages so artistically, that I must quote his remarks verbatim :—"Were the fossils of the Palæozoic on one side and those of the Mesozoic on the other, the difference would strike the observer as great as that between the brute-man sculptures of Nineveh and Egypt, and the God-man sculptures of Greece and Rome. The expression of human thought is not more clearly indicated by the remains of these ancient civilizations than the expression of creative thought is indicated by the fossil forms of the Palæozoic and Mesozoic earth periods."

Speaking of the particular advances of development in the various organic groups, the same clear and able writer thus proceeds :—"As the floral arrangements of the Endogen is formed by *threes,* and that of the Exogen by *fives,* all the ancient flowers and fruits are stamped by the normal number *three,* whereas five and three are equally normal in the Middle Age flora. So in the animal kingdom, the corals of the ancient Cycle had their septa in *fours,* while those of the middle are in *sixes.* In the ancient Cephalopods the arms are for the most part devoid of sucking disks, while those of the Middle Age are furnished with them; and in the chambered shells the ancient members have their sutural junctions plain and

simple, while those of the Middle Age have them foliated and of intricate patterns. The ancient crustacea are more larval-like in their segmentation, while the middle ones have the three parts distinct. The ancient fishes have all the unequally lobed tail, and the fishes of the Middle Age the higher structure of the equal lobes."

In this opening, or Trias period of the Secondary age, we may imagine a wide, low, sandy tract by the sea-side; the hills and cliffs of limestone, which at present rise boldly in Yorkshire, Derbyshire, and Somersetshire, having been recently elevated, and now standing as bulwarks along the coast line. Local elevation still gradually going on, and the foot-prints left by the birds and reptiles on the wet mud or sand of the river-bank or sea-shore being thus lifted beyond the reach of the returning tide or flood. On such shores various kinds of turtles, lizard-like and frog-like reptiles, and birds varying from the size of our small waders to that of an ostrich, probably wandered and waded; while plant relics tell of subjacent land, and a climate in which Calamites, Horse-tails, and Ferns could exist.

The term Trias is used in allusion to the *three* members composing this system, the Bunter or variegated sandstones, the Shelly limestone, wanting in England, and represented by the Muschelkalk of Germany, and the variegated marls, the Keuper of the Continent.

The Bunter Sandstone is the least interesting formation of the group; so barren of fossils, though attractive for its scenic effect. About Bridgenorth we see its soft red sandstones formed into beautiful rocky groups, their blood-red colour contrasting well with the surrounding foliage, while their varying surface is continually sought by "the mosses which creep and trail." The rocks of this formation are so loosely compacted for want of the cementing influence of lime, that it is a wonder that the "rush of after seas," as Mr. Roberts says, should have left any part behind. The same writer asserts that the Elm is essentially the tree of the New Red, and the Oak of the Old Red formations; but I have seen these trees so luxuriant upon the reversed formations, that I demur to the stability of his generalization.

The Shelly Limestone, better known as the Muschelkalk, is absent in England, but in Germany it is fully developed, consisting chiefly of a compact greyish limestone, occasionally varied by layers of Magnesian limestone, or of gypsum, and rock-salt. Here a great variety of shells are found. Ceratites, so called from their resemblance to a ram's horn, nearly related to Ammonites, the divisions of their chambers notched and ornamented, but not foliated as in the true Ammonites; of these a score of varieties are contained in the Muschelkalk. Numerous species of several genera, of the same tribe as the pearl-

oysters, are here present,—bivalve shells, fixing by a byssus, though free to remove; the hinge toothless and the unequal valves gaping near the beaks. Of these, Avicula and Posidonia are the best known. The beautiful Lily Encrinite is here immortalized, its twenty waving arms arising from a cup-like body, the stony stem threaded by animal sap. Ansted asserts that thirty thousand separate joints are employed in the formation of this curious and beautiful radiate animal.

The variegated marl, called Keuper, on the Continent, because of the copper pervading the beds, has its quota of fossils as well as a large share of mineral productions. The Keuper Sandstone is well exposed in various parts of Worcestershire and Warwickshire. At Shrewley Common, in the latter county, slabs of stone were found containing numbers of what seemed to be bivalve shells. But Professor Rupert Jones proves, after much research, that they are really small crustaceans, closely allied to the Estheria of the present day. In the same group of rocks, in India and Virginia, the same fossil is found prevalent. There is a bone of one of the huge reptiles of the age, the Labyrinthodon, in the possession of Mr. Brodie, from this same quarry, while the coexistence of the Batrachian and the Crustacean is further proved by a slab in the Worcester Museum, where the horny coat of the one, and the footsteps of the other, are fully developed.

Quarries near Warwick have supplied bones of that very curious Beak-Saurian called Rhyncosaurus.

One of these quarries, Coten End, has yielded a good number of bones and teeth of Saurians. We applied to the workmen to save any such for us, as we looked in vain among the waste for any organic remains. They told us that all that had hitherto been found were in a thin layer of loose rock, occurring between the heavy seams of sandstone. Mrs. Mowbray visited the quarry afterwards, and purchased three teeth—two were of a common type of Saurian, but the third showed the structure of a Labyrinthodon; it was submitted to Professor Huxley, who detected raised striæ upon it, and hence inferred it to belong to a yet undiscovered species of Saurian.

Professor Rupert Jones describes the general aspect of the head of the Beak-Saurian as resembling that of a bird or turtle, "the fore-part of the head having the profile of a parrot." No teeth are found in the jaws, and Professor Owen supposes that this reptile may have had its jaws encased by a bony or horny sheath, as in turtles. The footprints occurring on sandstones in the same neighbourhood, slabs of which may be seen in the Warwick Museum, are conjectured to be made by the Rhynchosaurus.

Mr. Symonds was told one day of a woman who possessed a fossil bird. He and some brother geologists took infinite pains to find her out; they

went hither and thither, often on entirely false scents, but at last they succeeded in finding both the woman and her fossil—it was not a bird, but one of these parrot-faced Rhynchosauris. But no inducement would prevail on the woman to part with her treasure; it was her husband's finding, and he was dead, so at all costs she would keep her bird.

Remains of a reptile somewhat between a lizard and a turtle, with a pair of long tusks in the jaws, have been found in rocks of this formation, in South Africa. Of living animals, it most nearly resembles the walrus.

Both footprints and remains, especially teeth, of gigantic Batrachians, have been found in various quarries about Warwick, and at Ombersley and Bromsgrove, while near the latter place a plant bed occurs with Calamites, Equisetaceæ, and other flowerless plants, shells are found in small numbers at Droitwich and Dinhampstead. The Foxholes quarry, in the Malvern hills, also supplies plant remains; it is in the Keuper sand. Footsteps, supposed to be of birds, have been found in New Red stone-quarries at Storton, near Liverpool.

The Keuper marls are important as containing beds of rock-salt. How these beds came there seems to be a puzzling question to geologists. The simplest supposition is that by some upheaval of a part of the land an arm of the sea was cut off,

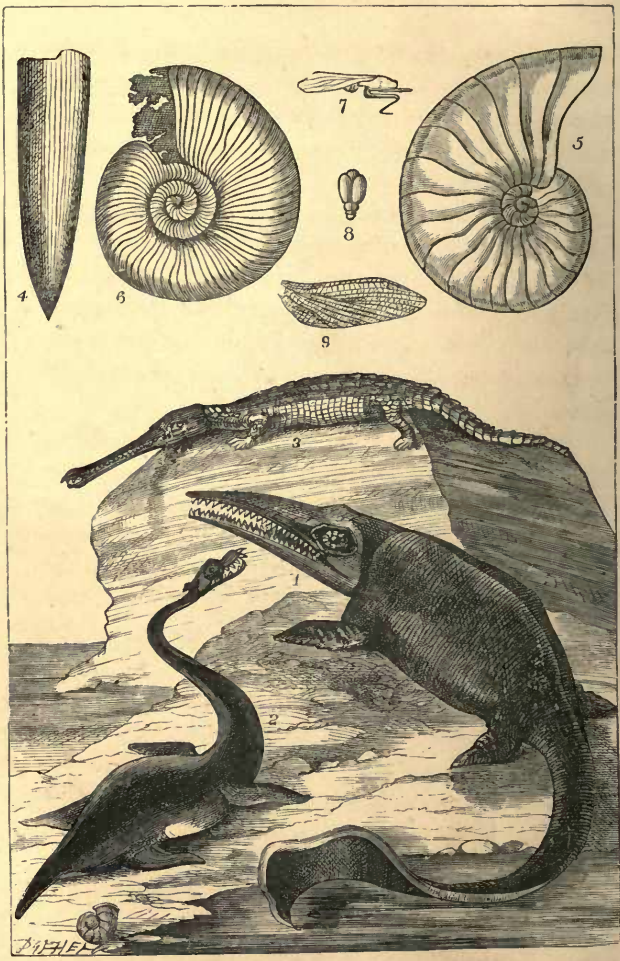


PLATE IV.—LIAS.

1. Ichthyosaurus. 2. Plesiosaurus. 3. Teleosaurus. 4. Belemnite.
5. Nautilus 6. Ammonite. 7, 8, 9. Insects.

and, the water evaporating, the salt became consolidated. But Professor Phillips argues, that in this case the deposit would be spread over a wide area, whereas, we more commonly find salt in great broad masses instead of layers, and gypsum in scattered masses above; and he suggests that developments of subterranean heat rendered by change of temperature, the calcareous matter insoluble over limited areas, and that "the limited deposits of salt happened in certain lagoons of the sea, exposed to local drying, as perhaps in Cheshire."

The Cheshire salt-beds lie along the valley of the Weaver, near Northwich; above them lies a bed of coloured marl 120 feet thick, it contains no trace of animal life. Sometimes the salt taken from these beds is pure, sometimes mixed with the red earth. Brine springs often issue from these beds. One bed is 100 feet thick, the others are not so bulky.

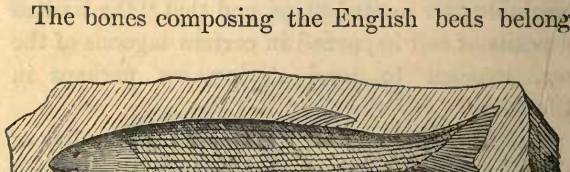
In Worcestershire there are salt springs in many places, as at Droitwich, Stoke-Prior, etc. Salt lakes in Siberia and Patagonia occupy depressions in the plains, but these are trifling in comparison to the Cheshire salt beds, being generally three feet in thickness at the most.

A bone bed lying between the Keuper marls and the basis of the Lias, marks the sudden destruction of animals over extended areas. It is found at Axmouth in Devonshire, and Westbury in

Gloucestershire—places fully sixty miles apart; it is never thicker than two feet, and often only two or three inches in depth. A stratum of the same nature occurs in Wurtemburg.

Rocks near Rowington have yielded two impressions of fish, one very perfect, the other fairly so but for the accident of a careless quarryman.

The bones composing the English beds belong



TRIAS FISH.

generally to reptiles of the frog and lizard tribes, such as have been already discussed; and many fishes characterized by a Saurian resemblance or by the peculiarities of their teeth, as Pointed-tooth, Hump-tooth, Thorn-tooth; or by the form of their scales.

The Triassic formation covers a considerable area in England. Commencing on the coast of Durham by the Tees' mouth, it extends through Yorkshire and Nottinghamshire, then spreading out among the Midland counties, it forms the prevailing rock in Leicestershire, Staffordshire,

Warwickshire, and Cheshire; then continuing through Worcestershire and Gloucestershire, it gradually narrows to the South-east shores of Devon, forming the picturesque cliffs of Dawlish, and the adjacent coast line, through which the railway trains play at hide-and-seek. The same rocks occur in patches on the Western coasts and islands of Scotland, and on the opposite coast of Ireland. It is more fully developed in the Alps in Eastern France, and in Germany, as also in the United States and Central Africa.

The best land upon this formation for farm culture is situated in the vales of Taunton and Exeter, whilst the soil lying over the sandstones of Warwick and Nottingham is of little value. These sandstones, though soft when taken from the quarry, harden by exposure to the atmosphere, and form a fair building material in the districts where they occur.

CHAPTER VII.

LIAS SYSTEM.

"For is it not true,
In yon limestone blue,
On the mountain steep,
In the valley deep,
Are the skeletons of the dead?"

CRICHTON.

BEDS of mud deposited in horizontal layers, from which term the name Lias is supposed to be derived, characterize this stratum, the lowest member of the great Oolitic group. The ocean currents of these comparatively quiet seas, washed trunks of trees from distant islands, and to them were attached clusters of Crinoids, as we see barnacles clinging at the present day. These were of the species with five-sided pillars, called Pentacrinites, the bead-like joints of the column almost resembling stars pierced in the centre,

while from the cup stony arms stretched in every direction, and thus the driftwood bore onwards in the current multitudes of stony scavengers, collecting the putrescent matter from the waters. Bivalves related to our oysters peopled this sea, leaving their remains in large beds. Brachiopods lived anchored to the submerged rocks; fishes in mailed armour darted hither and thither in deep water, pursued by sharks and gigantic water-reptiles; while Cephalopods, relations of the Nautilus and Cuttle-fish, eluded danger as best they might. The shallows and mud-banks had their population allied to crabs and lobsters, over which the Plesiosaurus exercised his reign of terror. And where land prevailed Calamites and Ferns were found overshadowed by palm-like trees, and insect tribes buzzed among the foliage.

This layer-like system is composed of dark limestone, blueish clays, and bituminous shells. A Lias cliff has a striped appearance, thin beds of limestone alternating with brown weathered surfaces; clays generally predominate, and small beds of coal are found in them. The surface becomes very muddy in wet weather, and offers the greatest difficulties to explorers of any formation. The beds charged with bitumen are liable to take fire, as is often the case among the Yorkshire cliffs, and they burn for weeks at a time. The coal found in this member of the formation is unimportant, but the Lias is valuable for

industrial purposes, as producing alum and iron. The former is procured from the Alum shale of the Yorkshire cliffs between Whitby and Huncliff. The latter is drawn in quantities from the iron-stone band bordering the Lias of Yorkshire, on its inland margin; in many places in Cleveland it has been worked with great success. It is also gathered along the shores in great nodules of iron-stone, the waste of the Lias cliffs.

No formation is more rich in fossils than the Lias, and no better field can be selected for young geologists than this, the early success in finding variety of fossils cannot fail to act as a whet to collecting. Well do I remember a case in point. An objectless stroll—heaps of stone by the way-side—we turned aside to look at them, when one of our party espied a large valve of the Giant Lima, nearly covering the upper surface of a stone; scarcely had his exclamation died on the air, before another heaved up a piece the size of a man's head, in which numerous ribbed shells of Rhynconella were embedded, and ere the search was ended we were triumphing over a large Ceratite measuring a foot and a half across. All our energies were taxed to the utmost to land our haul, or in other words to convey home our treasure, and the next morning saw us sallying forth duly armed with hammers, chisels, and canvas bags, for further explorations. This was amid the Lias limestone, a couple of miles from

Leamington, the stratum characterized as Lower Lias. We traced our friends home to their quarry by the track of the road metal, and there we set to work in good earnest. That noble bivalve, the Giant Lima, was there in profusion, some specimens measuring nearly a foot across, and sculptured in a fanciful pattern all over the shell, like an engraving on steel. There was the Lima Sulcata also, grooved and ridged from beak to mouth, uneven like its brother in form, one side straight and the other bowed, and the lower valve flatter than the upper, but nearly as large as the giant species. Specimens of our old friends the Terebratulæ occurred frequently, almond-shaped as in the older formations, and with the characteristic hole at the beak for the threads to pass through. Its ally, the Rhynconella, had many representatives, all with two lateral ridges on the one valve, and one central one on the other, giving the usual plaited appearance, while sharp ridges, more or less numerous in different species, gave a scalloped edge to the margin of the mouth. We found an Ammonite or two, appearing in this stratum as their first stage of life. The Ammonite is allied to the Nautilus of the present day, and to the Lituite of the Silurian. It is of a higher order of development than either. In the Lituite and Nautilus (Pl. 4, fig. 5), the divisions of the chambers are merely joined simply to the whorl. In the

Ceratite these divisions are arched and branched like a tree with its roots partly exposed. This construction gives great strength to the walls of these chambers, while their roofs are made firmer by arches and nodules, with which the surface of the Ammonite is generally adorned. The outermost chamber contains the body of the Cephalopod, the others are closed, their use is to add lightness to the shell, making it more suitable to its purpose of a float. Remains of a kind of cuttle-fish were in that quarry also. These Cephalopods without external shell are of a higher organization than the more sightly Ammonites and Nautili, and are gifted with means of defence; on the approach of an enemy they empty the contents of their ink-bag, the pigment from which the Sepia of commerce is formed, and thus ensconce themselves in a cloud which hides them from their foe. The Nautilus and Ammonites guarded by their shells were not in need of other means of defence. Above 500 species of Ammonites are found in the entire Secondary system; some with the outermost chamber armed with a beak are called Horned Ammonites, the external sculpture, size, and number of whorls distinguish the various species. The Cuttle-fish remains consist of a stony dart. They vary in thickness from a quill to a man's wrist, and are pointed like the dart, from which circumstance they are named Belemnites (Pl. 4, fig. 4). At first sight they

somewhat resemble the Orthoceratite of the Silurian age, but that is an external chambered cell more nearly allied to the Nautilus, while the Belemnite is the internal bone or shell of a naked Cephalopod. In some cases an upper chambered part is attached to the dart-like process, and in some instances remains of the colouring matter of the ink-bag have been detected. Forty different species are found in the British Secondary rocks.

Bivalve shells, triagonal in form, stood out like little bumps on the face of some of the blocks of limestone. We knocked off many of these, but did not get one entire. They were of the Nucula group, the hinge formed of a perfect row of teeth.

Our minds were now wholly occupied with Lias fossils; we examined the gravel of the garden walks, and picked up water-worn Belemnites and Gryphites, with corals from older rocks, and became more and more perplexed;—that gravel was fully explained at a later period.

On the Great Western line, between Leamington and Oxford, there is a deep cutting through Lias rock, and the stone is quarried there for lime. So thither we repaired to prosecute further research, and found the Gryphæa, the small oyster of the Oolitic system, in myriads, with our old friends the Limas, and a fair variety of horned and simple Ammonites.

Afterwards we had the pleasure of looking over Mr. Brodie's museum, where Lias remains abound. He has been most successful in finding insects in this formation, and showed us wings, and legs, and bodies, some nearly perfect, some more fragmentary, allied to nearly all the existing groups of insects. There we saw representatives of the beetles of to-day, of the wasp, the butterfly, the dragon-fly, and the common fly (Pl. 4, figs. 7, 8, 9).

Beautiful specimens of the large bivalve, Perna, are found in the quarries near Alderston in Worcestershire, all glittering with nacreous lustre, and there Pectons are found in very great abundance; a few poor specimens rewarded our search in the quarry near Leamington, and along the railway embankment partly formed of Lias stone.

One species of fern is found embedded among the oysters and cockles. The Lias Marl is famous as containing many bones of the Saurian tribe. This whole Oolitic period is well called the Age of Reptiles, for they abounded in the deep sea, on the sandy shore, and even in the air!

The slender Saurian, Plesiosaurus (Pl. 4, fig. 2), had a neck longer, in proportion to its body, than that of the swan, and a small bird-like head, constructed in a manner resembling that of a lizard, yet in strength of bone coming nearer to the crocodile; its jaws were long and spoon-shaped, and

bore nearly one hundred slender pointed teeth! The back was long, the vertebral column consisting of from eighty to ninety joints, and the creature measuring thirty feet in length. The ribs were strong and numerous, and stout bones were placed where shoulder and thigh-bones are generally situated, pairs of short flat bones proceeding from them, and ending in the four paddles of the animal. There is every reason to suppose that the Plesiosaurus could move about on shore more easily than a walrus, and that it fed on animal substances, living or dead. (Pl. 4.)

It was apropos of a skeleton Plesiosaurus that Mr. Hawkins tells such a diverting story in his "Book of the Great Sea Dragons." Two workmen in a quarry had found, on turning over a lias slab, the bones lying embedded; they speculated as to what the figure was, and decided that it was a "viery dragern, maybe one that stinged Moses." In horror at his supposed wickedness, they "have at him" with their mallets, smashing the skeleton in every part; and the geologist arrived too late to prevent the destruction.

The head of an Ichthyosaurus received no better treatment from the quarrymen of Worcestershire; being regarded as an unlucky discovery, it was thrown at once into the limekiln. Another stone-cutter made a mistake, in a different direction; finding the backbone and ribs of a young specimen, he went about boasting that he had

"found a fossil baby." Mr. Symonds relates the story in his "Stones of the Valley."

The Ichthyosaurus (Pl. 4,* fig. 1), was still more powerful than the Plesiosaurus; it somewhat resembled the recent porpoise, but had a larger head and larger paddles. Its snout was immensely long, vying with those of some crocodiles of the present day. The jaws bore an extensive row of strong teeth inserted in a groove in the bone, and the animal could afford to be careless in the use of them as new ones grew as often as the old ones were removed. A very large cavity was provided for the eye, and furnished with overlapping plates of bone, so that the opening for the eye could be made smaller or larger, as the creature needed; it was thus enabled to expand the pupil in deep water where but little light was present, to flatten the eye, so as to serve for far sight, and to protrude it when the object to be obtained was close at hand. In some specimens the cavity measures eighteen inches. The neck of this reptile was very short, and the backbone consisted of fifty vertebræ, and these were formed with two cup-shaped hollows, thus ensuring a flexibility of motion in water, such as the same form of vertebra endows the fishes with. The paddles exhibited a wonderful union of structure, the arrangements of the bones, and their great strength, and the addi-

*The drawings of these restored animals are, by his obliging permission, reduced from those of Mr. Waterhouse Hawkins.

tion of cartilage securing at once the power of the fin of a fish and the leg of a quadruped. Portions of the skin of this animal have been found, and by them we learn that it was thiek and covered with wrinkles, but without scales, somewhat resembling the skin of a whale. This powerful rival of the Plesiosaurus attained a length of from thirty to forty feet, and its four powerful paddles carried it through the waters with amazing speed, and were not ill adapted for locomotion on land.

The Pterodactyles, or flying reptiles, appear in this member of the Oolitic series, but they rather belong to a later period.

Mr. Symonds records, as the crowning glory of the Upper Lias shales, that as its clays receive and retain the water which percolates through the Inferior Oolite, and thus form a reservoir supplying the springs of the Thames, they are the father of that patriarchal stream ; for this reason he says he never can forget the Upper Lias.

The most remarkable part of this formation is a thin layer of yellow clay. In this bed numerous remains of fishes, insects, and crustaceans are found. Once more the enamelled scales of our old friends the ganoid fishes greet our eyes. Nodule after nodule, upon being split open, discloses the remains of a fish, while spines and teeth of sharks, star fishes, and insects add their remains to this teeming bed. The lance-shaped and somewhat bent spine, with its row of teeth

along one side, is a curious and interesting fossil. It is planted in the back of the fish, and a moveable fin is attached to it; thus it forms a sort of mast, worked by a muscle, and it turns the fin this way or that, in a manner greatly to aid the navigation of the fish.

The Upper Lias is well exposed at Whitby, and is very rich in Ammonites (Pl. 4, fig. 6). The fossil is thus designated because of a supposed resemblance in the shell to the horns of Jupiter Ammon. Before geology came forth to decipher the stony records of the rocks, these Ammonites were called Snake-stones. Walter Scott invested them with romantic interest in making the nuns relate—

> "How of thousand snakes, each one
> Was changed into a coil of stone
> When holy Hilda prayed.
> Themselves within the holy ground
> Their stony folds had often found."

The pious folk who regarded the fossils as petrified descendants of the Old Serpent, were perplexed to find them always without heads. The curiosity dealers remedied this want, by carving a head out of the stone in which the Ammonite was embedded; and they asked a high price for the so-called "perfect specimens." Three Ammonites form the arms of the town of Whitby.

A fine specimen of the Plesiosaurus was taken

PLATE V.—OOLITE.

1. Megalosaurus. 2, 3. Pterodactyle. 4. Iguanodon. 5. Hylæosaurus.
6, 7. Urchins. 8. Avicula.

from the Lias at Sandsend in that neighbourhood, which is now in the possession of Mr. Wood. From this point, the Lias crops out in every cliff, as far as Saltburn. In that most romantic coast-nook called Robin Hood's Bay, both the Upper and Lower Lias beds appear, exhibiting the characteristic fossils of both formations; impressions of Horse-tails (Equisetaceæ) are found here, and layers of bad coal, giving evidence of vegetable organization. Saltwick rocks have afforded good Saurian remains.

On the coast of Cromarty, as well as in several other localities in North Britain, Lias rocks appear. Hugh Millar describes a quarry on the coast of the Moray Frith so graphically, that we quote the passage:—"In the course of the first day's employment I picked up a nodular mass of blue limestone, and laid it open by a stroke of the hammer. Wonderful to relate, it contained inside a beautifully-finished piece of sculpture—one of the volutes, apparently, of an Ionic capital, and not the far-famed walnut of the fairy tale; had I broken the shell and found the little dog lying within, it could not have surprised me more. Was there another such curiosity in the whole world? I broke open a few other nodules of similar appearance, for they lay pretty thickly on the shore, and found that there might be. In one of these there were what seemed to be the scales of fishes, and the impressions of a few mi-

nute bivalves, prettily striated; in the centre of another there was actually a piece of decayed wood! Of all Nature's riddles these seemed to me to be at once the most interesting, and the most difficult to expound. I treasured them carefully up, and was told by one of the workmen to whom I showed them, that there was a part of the shore about two miles further to the west, where curiously-shaped stones, somewhat like the heads of boarding pikes, were occasionally picked up; and that in his father's days the country people called them thunderbolts, and deemed them of sovereign efficacy in curing bewitched cattle." It is not in Scotland alone that Belemnites get the name of thunderbolts; in many Lias districts in England they are associated with that legendary terror. Our author takes advantage of the first holiday to go and examine these rocks, and is well rewarded for his search. "We may turn over these wonderful leaves," he says, speaking of the layers of slaty stone, "like the leaves of an herbarium, and find the pictorial records of a former creation in every page. Scallops, and gryphites, and ammonites of almost every variety peculiar to the formation, and at least some eight or ten varieties of belemnite; twigs of wood, leaves of plant, cones of an extinct species of pine, bits of charcoal, and the scales of fishes; and, as if to render their pictorial appearance more striking, though the leaves of this interesting volume are of

a deep black, most of the impressions are of a halky whiteness. I passed on from ledge to ledge, like the traveller of the tale through the city of statues, and at length found one of the supposed aerolites I had come in quest of, firmly embedded in a mass of shale. But I had skill enough to determine that it was other than what it had been deemed. A relative, who had been a sailor on almost every ocean, had brought home a meteoric stone from the coast of Java. It was of cylindrical shape and vitreous texture, but there was nothing organic in its structure, whereas the stone I had now found was very curiously organized. It was of conical form and filamentary texture; the filaments radiating in straight lines from the centre to the circumference. I learned in time to call this stone a Belemnite, and became acquainted with enough of its history to know that it once formed part of a variety of cuttle-fish, long since extinct."

Still more famous for fossils of every class are the Lias cliffs of Dorsetshire. The landslip at Lyme Regis shows the character of the clay, and the fossil reptiles, shell-fish, and crab-like creatures testify to the abundant population of former seas, whose quiet oxidized waters favoured the preservation of animal remains, while its clays encouraged the growth of plants no more in those days than they do at present.

CHAPTER VIII.

OOLITIC SYSTEM.

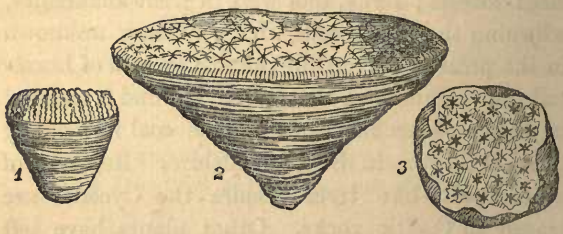
"And on the pavement lay
Huge Ammonites and the first bones of time;
. . . .
. . So that sport
With science hand in hand went."

TENNYSON'S "PRINCESS."

THE Oolite is so named from two words meaning *egg* and *stone*, because of the roe-like grain of which many of its rocks are composed; when these grains are very large they are likened to peas, and the rock called *Pisolite*. These grains generally contain a minute centre of sand, around which a lime-coating has formed, thus maintaining a further resemblance to an egg. The strata are all marine in their formation, but as they contain broken shells and corals it is probable the waters

were shallower, and there were upraised beaches and sandbanks, and adjacent land. This Oolitic land nourished forests of noble trees, the allies and predecessors of our pines and yews; at least fourteen different species of conifers are preserved as fossils in this system. Cycads, an order intermediate between conifers and ferns, stunted in their growth, but graceful and plume-like in foliage, formed the brushwood of those ancient forests; ferns, too, were in great abundance, adorning the pine woods with a verdure unknown in the present era; while the vast growth of horse-tail and calamite in the marshy ground is testified by the considerable seams of true coal formed by them at Brora, in Sutherlandshire. Remains of other palm-like trees besides the Cycads are traced in Oolitic rocks. Other plants have left signatures behind them. But the essential character of the Oolite is reptilian; the Crocodile-like Saurians were still the tyrants of the waters; fresh-water Saurians peopled the rivers, and infested their banks; bird-like reptiles soared in the air; and thus air, and land, and water, were peopled by reptiles. Radiates abounded in the ocean; the predecessors of our Sea-Urchins occur in immense variety, corals and sponges become prevalent again; brachiopods still adhere to the rocks; oysters, cockles, and scallops, with their relations in every degree people the waters; nerites, trochites, and limpets wander on the rocks, and the vast tribe of ammonites and other cephalopods sail upon the

waves. Placoid and ganoid fishes still prevail. The advance of creation is indicated by the appearance of warm-blooded animals: the Amphitherium and Phascolotherium of the Stonesfield Slate, Oxfordshire, supposed to be marsupial (pouch-bearing) Mammals, and the Plagiaulax of the Purbeck beds of similar structure, denote the first dawn of Mammalia. Birds, too, appear among creation, not in mere footprints, but with well-



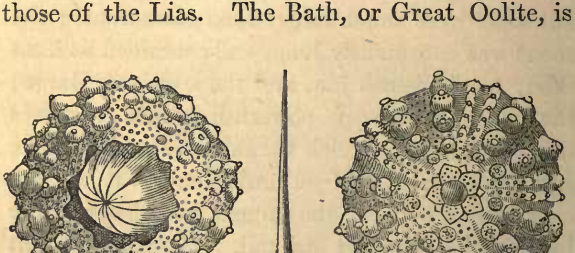
OOLITIC CORALS.

preserved skeleton, and clearly defined feathers; and insects still prevail for their maintenance. Indeed the yellowish limestones of the Oolite are perfect treasure-houses of the records of past creations; yet all the types are essentially Secondary, differing materially from those of primary rocks, and dying out when the Chalk system closes the Secondary series.

The inferior Oolite, a calcareous or limy stratum, rests upon the Lias rocks; its stone is used for building purposes, and shells and radiates are found in it, some in a good state of preservation, but many very imperfect; it also contains corals.

Near Bath a bed of fuller's earth tops this stratum; a fine clay much used in cleansing woollen goods. Near Oxford a sandstone formation, called Stonesfield Slate, belongs to this member of the Oolite, very important as containing fossils. Here remains of the famous Pterodactyle (Pl. 5, figs. 2, 3), have been found; flying reptiles of repulsive appearance. In general form they most resemble bats, but some were much larger than cormorants; the snout was enormously long, and contained at least thirty teeth in each jaw, and the eyes very large; the wings were very powerful, formed of bones like fingers, upon which the skin was stretched like silk across the ribs of an umbrella, but it did not only extend between the fingers, but also from the last finger to the feet and tail. The thumb is left partially free, and serves as a hook by which the animal suspended itself; but the toes were long and exposed. By a singular contrivance the creature was able to walk and swim as well as to fly. The bones of the arm, wrist, and hand correspond with those of the legs, but the joints of the little finger were increased to five, and each joint enormously lengthened: thus the little finger became longer than the whole body, and to it the membranous wing was attached, being fastened likewise to the arm, body, and hinder extremity. The arm could be extended without expanding the wing, and the creature could use the arms and legs in walking or swimming, and, by stretching out the wonderful little finger, vary its exercise by

flight. In the same rock the remains of pouch-bearing animals are found—both insect and herb-eating—related more nearly to the opossums than to any other living mammals. In the slates here, or in the answering formation on the Continent, remains of calamites are found, and many varieties of beetles and other insects, as well as bones of Saurians, nearly related to, though differing from, those of the Lias. The Bath, or Great Oolite, is



1. VENT OF CIDARIS. 3. SPINE OF DITTO. 2. MOUTH OF DITTO.

very fully developed about Bath, and has its full share of fossil contents. The Pear Encrinite and others of that tribe of complicated structure are here, star-fishes of varied size and proportion, sea-urchins in profusion, and the allied genus of Cidaris. The fossil remains of this animal are familiar to every collector,—round, inflated on the upper surface, and covered with knobs, arranged in lines like the pattern in a kaleidoscope. Each of these knobs was a true ball-hinge upon which

a club-like spine was fitted, capable of turning in any direction; occasionally a few of the clubs are found attached in the chalk, but generally they are lying scattered around or near the main body of the animal. These clubs were used as spades in the soft sand, and enabled the creature to move along very rapidly. The Nucleolites (Pl. 5, fig. 6), as common as the Cidaris, are oblong, their shell rounded in front and flat behind, the mouth is nearly in the middle. Echinites (Pl. 5, fig 7), are there also in considerable variety, all resembling more or less the sea-urchins of our present shores. Bivalve and univalve shells are abundant in this formation, as well as the Brain and Star-corals. The stone from this stratum is excellent for building, it forms part of Henry the Seventh's chapel at Westminster Abbey.

The Bradford Clay, so called from its full exposure about Bradford, in Wiltshire, is of a greyish colour; its most characteristic fossil is the Pear Encrinite, which, from its abundance in those rocks, is sometimes called Bradford Encrinite. Some bands of tough brownish limestone, alternating with layers of the grey, contain bivalves and other fossils.

Succeeding the Bradford Clay, in the regular order of the series, we have the Forest Marble, a very fossiliferous limestone, frequently crystalline, and which is principally developed in Whichwood Forest, Oxfordshire. It encloses quantities of

broken-up Encrinites, the spines of Cidaris, corals, and small bivalves.

Beds of coarse shelly lime and sandstones, abounding with fossils such as have been already described, and called Cornbrash by some authors, completes the group distinguished as Lower Oolite.

The Oxford Clay, the first member of the Middle Oolite, rises to the surface in Dorsetshire, Cambridgeshire, Lincolnshire, and Yorkshire, but its best development is about Oxford; hence the name which has been applied to it. It consists of a bed of stiff, pale blue, calcareous clay, and at its base lies a shelly and sandy limestone, entitled Kelloway Rock. This stone abounds in fossil shells.

Great quantities of Ammonites and Belemnites occur in the Oxford Clay, but are seldom in a perfect state. Nodules of iron pyrites, called by the country people "Thunderbolts," abound in these rocks.

In the succeeding member, the Coral Rag, we have the full exposition of the corals of the system; in many parts the rocks consist only of continuous beds of petrified corals, generally retaining the position in which they grew, and sometimes forming masses fifteen feet thick. Thus the corals of Oolitic seas are in abundance with those of the mountain limestone, and with the coral reefs of the Silurian. Madrepores, Brain, and Star-corals in many varieties form these reefs.

The Upper Oolite, as developed in England, consists of two members,—the Kimmeridge Clay and the Portland beds. The first is formed of beds of blue slaty clay and bituminous shale, in which an inferior kind of coal, known as Kim Coal, is found. It is used locally, but is not of much value. Sir C. Lyell considers its bitumen to be partly of animal, partly of vegetable origin. The rock takes its name from Kimmeridge; it is very rich in fossils near Aylesbury, in Buckinghamshire, but the fossils are difficult to preserve. The lithographic limestone of Solenhofen, near Munich, is of the same age as the Kimmeridge clay of England, and it has lately become famous as containing a fossil bird. Many have been the hopes of geologists that at this or that time the remains found were really ascribable to the feathered race, but each time the opinions of the most competent judges have referred the bones and even feathers to the Pterodactyles. Footprints in slabs of New Red Sandstone and Oolite Rock have been distinctively ascribed to birds, but what had become of their bodies?

Recently, however, M. Von Meyer announced that a true feather was found in the slate at Solenhofen, "agreeing in all its parts so entirely with the feather of a bird, that it is impossible to distinguish it therefrom." Through the exertions of Professor Owen and Mr. Waterhouse, this fossil has been procured for the British Museum. One leg of the bird is quite perfect, and also the wing

bones, and some of the other bones; the merry-thought is lying between the wings; the ribs, etc., are scattered as if the body had been torn, and eaten by some animal wandering on the shore of that Oolitic sea. The vertebræ of the long tail are well preserved, and the feathers are attached to them in pairs; there are forty feathers and twenty vertebræ, which become smaller towards the end, thus showing a remarkable contrast to the tail vertebræ of existing birds, which grow larger towards the end. Mr. Woodward traces in this contrast a similarity to the difference of the ancient fishes to those of present seas; in these the tail-fin springs from the last of the vertebræ, in those the vertebral column is prolonged along the upper lobe of the unequal tail.

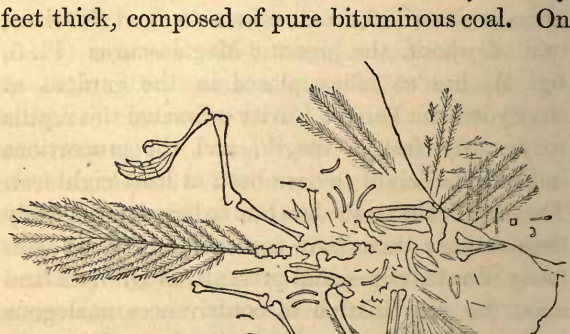
The impressions of the feathers are microscopically perfect, and it follows by analogy that "there must have been a beak to keep them in order with." Professor Owen is of opinion that this creature is a true bird, and he has named it Archæopteryx. The same rocks present abundant cuttle-fish, ammonites, nautili, crustacea and fishes. Also beautifully preserved remains of insects, and of a kind of shrimp.

The last stratum in the Oolitic series is designated as the Portland beds; these are best developed in the South of England, especially in the Isle of Portland, and at Weymouth, Dorsetshire. The freestone of the system is very valuable as a building stone; it is soft when taken from the

quarry, but becomes hard by exposure; St. Paul's Cathedral and many public buildings are built of it. Fossils abound in these beds. Ammonites, gryphites, nautili, terebratulæ, trigoniæ and other bivalves, with Sea-urchins and corals; bones, too, of Saurians, some belonging to those already described, and others to land Saurians, one of whom, the gigantic Megalosaurus (Pl. 5, fig. 1), has an effigy placed in the gardens at the Sydenham Palace. Cuvier estimated this reptile to be fifty feet in length, and the proportions indicate his height to have been at least eight feet. The form of the teeth show him to have been entirely flesh-eating; these have cone-shaped crowns with finely serrated edges, and presents, as Dr Buckland says, "a combination of contrivances analogous to those which human ingenuity has adopted in the construction of the knife, the sabre, and the saw." The restored specimen in the gardens of the Crystal Palace measures 37 feet in length, and 22 feet in girth. The best remains of this animal are found in the Stonesfield slate, but they occur also in the Purbeck limestone and in other members of the system.

The Oolitic formation affords a fair variety of materials for industrial purposes: the freestones of Bath, Portland, and Caen for building; the limestones for mortar; the Forest and Purbeck marbles for ornamental architecture; Fuller's earth for the cloth trade; the Jura limestones for lithographic

blocks; coal at Kimmeridge and Brora, also in the East Indies, and, most important of all, in Virginia. Here, the coal beds—I quote from Sir C. Lyell—"rival or even surpass those of older date in their richness and the thickness of their coal seams. The main seam is from thirty to forty feet thick, composed of pure bituminous coal. On



ARCHÆOPTERYX.

descending a shaft 800 feet deep, in the Blackheath mines in Chesterfield county, I found myself in a chamber more than 40 feet high, caused by the removal of the coal. The coal is like the finest kinds shipped at Newcastle, and when analyzed yields the same proportion of carbon and hydrogen,—a fact worthy of notice when we consider that this fuel has been derived from an assemblage of plants very distinct from those that have contributed to the formation of the ancient or palæozoic coal."

CHAPTER IX.

WEALDEN SYSTEM.

"'So careful of the type!' but no,
From scarped cliff and quarried stone
She cries, 'A thousand types are gone!'"

Above the strata characterized as Oolitic proper, we have the Wealden formation, so called because it is developed principally in a tract of country between the North and South Chalk Downs, occupying a considerable area in Sussex, Kent, and Hants. Dr. Mantell, the most successful explorer of this formation, describes it as "a series of clays and sands with subordinate beds of limestone and shale, containing freshwater shells, terrestrial plants, and the teeth and bones of reptiles and fishes; univalve shells prevailing in the upper, bivalves in the lower, and Saurian remains in the intervening

beds; the state in which the organic remains occur manifesting that they have been subject to the action of river currents, but not to attrition from the waves of the ocean." Page adds, "As typically developed in Kent and Sussex, it seems to occupy the site of an ancient estuary, which received the clay and mud of some gigantic river, whose waters bore down the spoils of land-plants and animals to be entombed along with those of aquatic origin." Calcareous matter was first deposited in this estuary, and numerous fresh-water mollusks allied to the Limnæadeæ were entombed in it. A thick layer of sand succeeded upon this, variegated in horizontal sheets with ironstone, and sometimes interstratified with mud, and finally muddy matter prevailed. De la Beche suggests that the solid ground beneath the waters suffered "a gradual depression, which was as gradually filled with imported matter; then the sea entered again upon the area, not violently, for the Wealden rocks pass gradually into the Cretaceous, but so quietly that the mud containing the remains of terrestrial and fresh-water animals becomes covered by sands replete with marine exuviæ."

Here we find fresh-water shells and crustaceans, land-plants and insects, estuarine fishes, aquatic crocodiles, and huge herbivorous and carnivorous quadrupeds.

Three different groups of rocks characterize the Wealden formation.

The Purbeck beds, developed so richly in the island from whence they take their name, consist of fissile limestone and slaty clay. Remains of turtle and Saurian reptiles are found in this rock; but the fossils consist principally of varieties of fresh-water shells, Paludina or pond-snails, Cyclas, and Unio. The rock entombing these mollusks was formerly much used as a marble in the interior of churches.

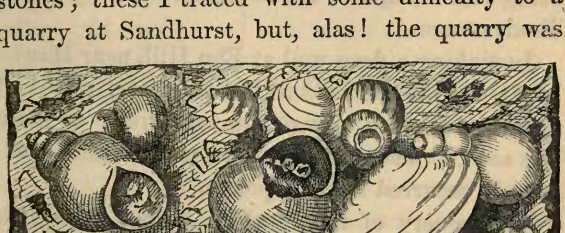
The Hastings sand is well exposed about Tunbridge, where the line of the South-Eastern Railway passes through numerous tunnels cut in the rocks. It exhibits alternating beds of sands, grits, and clays, and occasionally contains lignite. Its development in Tilgate Forest is rendered famous by Dr. Mantell. It is said that Mrs. Mantell first discovered teeth in these rocks when walking in the forest, and the doctor immediately set about discovering what these teeth could possibly belong to. Upon consulting Baron Cuvier he was assured that the teeth denoted an herb-eating reptile, and when he afterwards compared them with those of an Iguana in the Royal College of Surgeons he was struck by their similarity. Mr. Bensted, of Maidstone, afterwards had the happiness of finding an almost perfect skeleton with similar teeth in a quarry of the Greensand formation, and the animal thus rescued from oblivion received the name of Iguanodon (Pl. 5, fig. 4). Belonging to the reptile order, it is yet more akin to the crocodiles, thirty-

four feet long and twenty thick, with a head measuring a yard from snout to neck, and a tail five yards long, legs and thighs of enormous thickness, and gigantic feet armed with a claw five inches long. It probably fed on Cycads, and other shrubs, as the remains of these are found along with the teeth of Iguanodon in the Wealds of Kent and Sussex, and in the Greensand of Maidstone and the Isle of Wight. The Hylæosaurus (Pl. 5, fig. 5), another land reptile, of taller stature and more massive proportions, belongs to the same formation. The skull and teeth of this reptile have not been found, but from the other bones Professor Owen divines their structure. It was covered with scaly armour, and Dr. Mantell supposes that a fringe of broad bones ran along the back of the animal. Dr. Mantell found the remains on a slab of stone in Tilgate Forest.

Animals of the crocodile order are also found in this formation, various fishes, and a considerable number of shells.

The Wealden Clay, the third and uppermost member of the system, forms the basis of the soil of the Weald of Kent and Sussex, and contains bands of limestone and sandstone. The Sussex Marble is Wealden limestone; it is a conglomerate of fresh-water shells, now univalve now bivalve, forming the concrete, but seldom the two together. Naturally it is a gray stone of somewhat crystalline texture, but is sometimes coloured with iron, when the white contour of the shells appears in strong

relief, and the effect of the contrast on the polished surface is very pleasing. Bands of this rock alternating with the iron-tinged sandstones are found all over the district of the Weald. Upon some ornamental rockwork in a newly-formed fernery, I detected casts of large bivalves in the stones; these I traced with some difficulty to a quarry at Sandhurst, but, alas! the quarry was



SUSSEX MARBLE.

already filled up and a crop sown over it. The fossils were kindly presented to me; they were of the oyster group, and must have been deposited during one of the marine incursions. Ferns and palm-like trees are found in this formation, and Mr. Brodie has procured beetles, dragon-flies, and wood-lice from it also. An intelligent Kentish boy brought me a small iron nodule one day—he had been more than once with his father on fossilizing excursions:—"Look," he said, "I have really dug this out of my own garden! It must be a fossil sweetie which Adam and Eve gave to Cain and Abel!"

While yet the oak forests which partially covered the Weald were in existence, the ironstone was diligently quarried; scarcely any large village is without its legend of a smelting-house. But as the forests dwindled and it became necessary to import fuel the smelting ceased, the stone not being rich enough in ore to pay for working at the disadvantage.

In sinking a deep well at Elm Hill, near Hawkhurst, on this formation last summer, pieces of cannel coal were brought up; no trace of fibre was seen, it was not lignite but hard shining coal. It only occurred in small pieces.

The scenery of the Wealden formation is rich and pleasing. Hills of low altitude, yet giving much variety to the view, clothed with oak trees of unparalleled beauty, and also with chestnut and elm and varied with graceful hop-gardens, rich pastures, and fields of waving corn, present thoroughly typical English scenery. The only failing point is the unimportance of the streams; while the eye luxuriates in the wealth of verdure it seeks in vain for the rock-bedded rivers of the older formations.

Here closes the Oolitic period—its palms, ferns, and horse-tails, its freshwater univalves and bivalves, its beetles and dragon-flies and wood-lice, appear no more. In pour the waves of a quiet sea, admitted by the depression of the land, not encroaching by their own fury, and the next formation is wholly marine.

CHAPTER X.

GREENSAND SYSTEM

"An mony a plant an weird auld tree,
Weel kenned by earefu' giaumering ee,
I'th staines appear;
Uncanny things wad fright the de'il,
Wi' fou' mouthed beasts, wha make ye feel
Maist unco queer."

ANON.

THE sea, which crept quietly and noiselessly over the depressed beds of the Weald clay, deposited layers of sand, the *débris* of olden rocks, tinged with the green silicate of iron to such an extent as to give a name to the rocks thus formed. But there are exceptions to the greenness of the Greensand; it is sometimes found white, or tinged with ochre, or the common reddish hue of iron oxide. These deposits took place in a sea probably of middle depth, with land at some distance. The

marine Saurians continued while radiate animals were increasingly abundant, and various families of mollusks flourished in great numbers. After the first stratum of Greensand, a bed of blue clay, called Gault, was formed, containing characteristic fossils, and beds of Fuller's earth. After this, another stratum of sand was deposited, which we call Upper Greensand.

This Greensand formation is moderately developed in England, it borders the Wealden strata, appearing from Maidstone to Tunbridge, elsewhere it crops out from beneath the Chalk, as in the Isle of Wight and along the margin of the Downs.

That useful building stone called Kentish Rag lies at the base of the Lower Greensand in that county. It is a source of much trade to Maidstone, being quarried in that neighbourhood to a great extent. The liability to encroachment by the sea of that low tract of line known as the "Marshes" necessitates "sea-walls," and the Ragstone is in constant requisition for this purpose. All the bridges of the district are formed of the same stone, and when burnt it makes a lime of very superior quality. Mr. Bensted states, that when the pier of the centre arch of Aylesford Bridge was removed, the mortar formed of Ragstone lime was so strong that the stone could only be forced from together by blasting with gunpowder. Rochester Castle, and many of the London churches, are built of this stone.

One quarry near Maidstone, the property of the noted geologist, Mr. Bensted, is called the Iguanodon quarry, because the most perfect remains of that most extraordinary animal have been found there. Many layers of building and road-stone alternate with softer rock, called in the district "hassock," and one or two of limestone.

In these lower lays, fossil zoophytes allied to our Flustra are found, with abundance of Gryphæa and the three-cornered Trigonia, the "horse heads" of the Portland quarrymen. The remains of a marine turtle have been found here associated with Scaphites, an ally of the Ammonite, the whorls of which coil round at each end, so that the inner ones look like a reversed prow, and the last chamber, which is at first straight and then recurved, resembles a boat and stern, hence the term Scaphite, which means a *skiff*. Higher up in the quarry is a layer with larger Trigoniæ and sponges, then one with small Belemnites and fresh teeth, and a bone of that curious fish called the Chimæra. Mr. Bensted relates that a fish of this family, now existing in Arctic seas, is generally seen in a herring shoal, and is hence called "King of the Herrings." Teeth of other contemporaneous fish have been taken from these beds. Here, too, are found markings of seaweed, cones of a kind of fir, and one splendid trunk, supposed to be that of the Dragon tree. This tree belongs to the Asparagus tribe, and in its internal organiza-

tion resembles the Palms. From trees of this family the pigment used by wood-grainers, called "Dragon's Blood," is drawn; they inhabit dry soils, and are found on the seashore at moderate altitude, and even on mountain heights three thousand feet above sea level, in India, China, and South Africa.

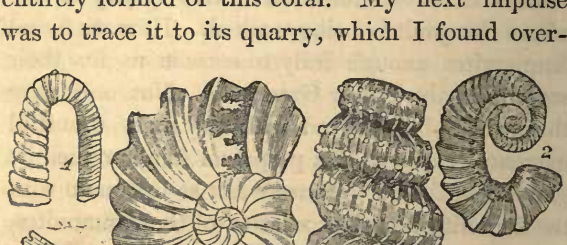
The Speeton clay, so well developed at the place from which it takes its name, near Scarborough, belongs to the Lower Greensand; it consists of dark-blue layers containing nodules of ironstone. The stratum appears again at Port Famine in the Straits of Magellan, and is supposed to extend all that distance. That curious ally of the Ammonite, the Ancyloceras, is characteristic of these beds; its shape is first curved, its whorls being separate, and then it is straight, and curved round like a hook.

In a Greensand quarry, near Warminster, in Wilts, I have found a great variety of small fossils. Our old friend the Terebratulæ were there, so readily known by the hinge-hole for the attaching thread to pass through. Venuses of two forms were among the specimens, one bean-shaped, the other angular, the valves quite perfect, and exquisitely striated; I also got some shells resembling small Pectens. But the most frequent fossils were of the Echinus family, these occurred in great numbers. The Cidaris, or Turban Sea-urchin, round in form, its knobs now denuded of

the club-like spines which should have turned upon them, were arranged in equal rows from the summit to the base of the ball, the mouth occupying the centre of the under surface; this had many representatives in the quarry. Morsels of coral were there too, and small sponges, with an occasional whorl of Ammonites.

Less than two miles from this quarry is one where the gault is being worked. Here we found Ammonites enough fully to console us for their scarcity in the Lower Greensand. Not only were they whole, but covered with the most beautiful nacreous lustre, as if a perpetual rainbow shed its glow upon them. We were not so fortunate with the Turrilites, another relation of the Ammonites, where the whorls are raised one above another, like a staircase-shell; portions of this characteristic fossil rewarded our search, but no well-preserved specimen. In Kent and Sussex this gault formation is well developed above the Ragstone, and contains Ammonites and Hamites; these last resembling a crook twice turned but with the large outer chamber straight. Shells of the bivalve Inoceramus, so common in the Chalk, also characterize the gault, or "Black Land" of Kent, as do likewise those of the Dentalium and Rostellaria. The soil on this formation is very difficult to plough, and ten oxen are often employed to work one plough, but the land is capable of being brought to a high state of cultivation.

The Upper Greensand lies above the gault. My first knowledge of it and its fossils was gained from a heap of stones placed for mending the road traversing the valley of the Dever, in the Wiltshire Downs. One lump speckled over with starry coral, attracted me, and upon procuring the aid of a stone-breaker I found that the block was almost entirely formed of this coral. My next impulse was to trace it to its quarry, which I found over-



1. HAMITE. 2. SCAPHITE. 3. BELEMNITE. 4. TURRILITE. 5. AMMONITE.

looking the gault bed. Here the rock was yellowish, and it required a stretch of faith to believe it a member of the *green* sand. More corals were found in the quarry, but the stone was hard, and the fossils unattainable; only splendid Pectens, all covered with well-preserved spines, were sculptured in relief on the faces of the blocks ready for carting away; no scallops of our shores have their ridges and warts more perfectly developed, than had these fossils of the Crockerton

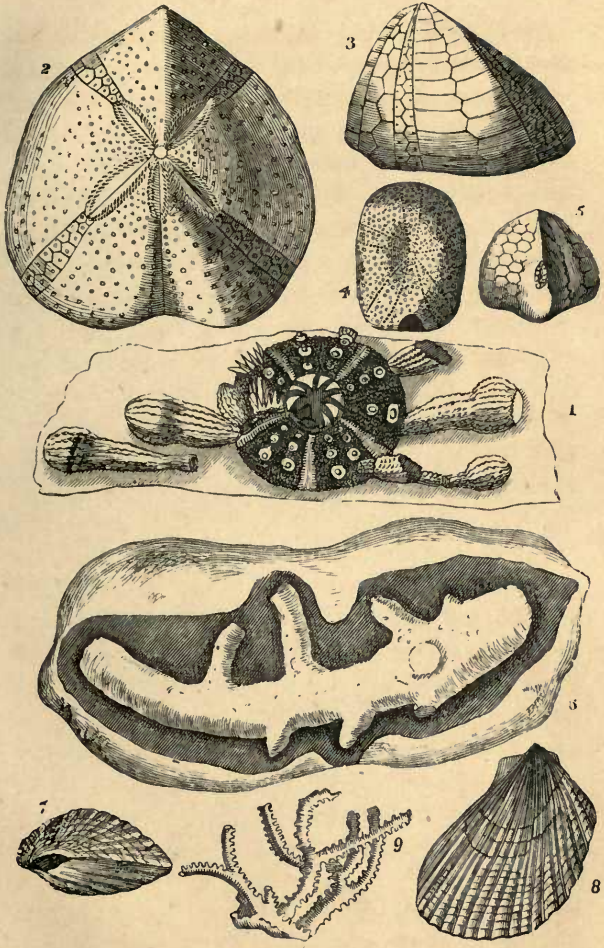


PLATE VI.—CHALK.

1—5. Urchins. 6. Sponge in Flint. 7, 8. Shells. 9. Coral.

quarry. In the low land between this and the higher part of the valley of the Dever, the Upper Greensand and gault disappear, and the rock that appears is the Lower Greensand, but then the Upper Greensand is again visible.

A scientific clergyman of the neighbourhood, aware of the existence in this formation of the deposit called Molluskite, supposed to be derived from the soft parts of molluscous animals, and also aware how valuable the bony matter associated with this Molluskite is, as a dressing for land, believed he had made a very advantageous discovery when he picked up fossils characteristic of the formation in a ploughed field. He hastened to inform the farmer of his good luck, but the man disbelieved equally in his pastor and in science, and turned on his heel disregardful. But in a quieter and less sulky moment he thought better of the matter, for to the clergyman's great amusement when next he passed that way he saw a hole cut in the said field, and the Upper Greensand rock fairly exposed. But as the farmer did not find the coveted prize at once, and would not ask counsel, he desisted from his work, and the only use of the excavation was when a stray geologist went thither fossilizing. Well do I remember the day, when accompanied by a geological student from Cirencester College and other friends, we clambered down into that hole. A cutting east wind was driving mercilessly across the adjacent

Downs, and the bleak country afforded no shelter; even the protection of the walls of the excavation was welcome! We found the Spatangus, an oval Sea-urchin with very small tubercles; two or three Ammonites, a Trochus, and an oyster.

Close to Warminster this formation appears again in beds of loose sand. With only the aid of a gardening knife we disengaged a number of shells of the *Gryphæa Vesiculosa* from the rock; the lower valve is flat the upper much inflated, straight on one side, considerably curved on the other, and coarsely wrinkled. The shells are perishable, the cavity filled with the loose green-tinted sand.

The Fire-stone used for the construction of glass furnaces is a member of the Upper Greensand; it combines an admixture of lime with the prevailing sand.

Phosphatic nodules, now ground down and used as a manure, are obtained from the gault and Upper Greensand of Farnham, in Surrey; they are valuable as containing a large percentage of phosphate of lime. Lyell's explanation of these nodules is, "doubtless of animal origin, and partly coprolitic, probably deprived from the remains of fish." This was what the Wiltshire farmer wished to find, but was too proud to ask guidance to.

This Greensand group is properly the lowest member of the Cretaceous, or Chalk system.

CHAPTER XI.

CHALK SYSTEM.

1. Chalk Marl.—2. Lower Chalk.—3. Upper Chalk.

"For even as a limestone cliff is an aggregate of countless shells,
One riddle concrete of many, a mystery compact of mysteries,
So God, cloud-capped in immensity standeth the cohesion of all things." Martin Tupper.

The Chalk strata are the uppermost in the Mesozoic or Secondary system; the Chalk and Greensand together form the important group of strata characterized as the Cretaceous; the Flora and Fauna of the Secondary period die out at the close of the Chalk, and an entirely new set of forms appear. The stone is composed of carbonate of lime, soft and earthy in its general development, though becoming crystalline as statuary marble, when brought into contact with igneous rocks. It is a truly marine deposit, and though occasional plants indicate river drift, yet most of

the forms entombed in such abundance in its sediment are wholly of sea inhabitants. These plants as well as the corals and water reptiles indicate a tropical climate. Ehrenberg examined portions of chalk rock by a microscopic analysis, and he states that one cubic inch contains the remains of many millions of foraminifera, creatures inhabiting chambered cells allied to the nautilus and ammonite, though differing in the fact of *all* the cells being tenanted. He has likewise detected microscopic seaweeds in the chalk.

This formation is one of the most easy of recognition, whether we consider the appearance of its rocks or its geographical features. Although occasionally varying in colour to a grey or reddish tint, it is generally pure white, easily marking anything or everything it touches. Following the line of the Lias and Oolite it extends diagonally across England, from the North-East to the South, and South-East, and everywhere it is known by its rounded hills and valleys; the former called Downs; it bears a short sweet herbage, excellent food for sheep, the tinkle of whose bells is ever intimately associated with all chalk explorations. The Downs are generally nearly bare of trees, and the rains of heaven are quickly absorbed and sink to the strata beneath, where they form deep wells issuing forth into lower ground.

The flints which enter so largely into the composition of its rocks are composed of pure silex,

with a little lime and iron; they have generally a coral or sponge in their centre, round which the silex has gathered. In the Chalk districts they build walls of these flints, and, mingled with the soft chalk, or chalk marl, they make excellent road metal.

The Chalk Marl, the lowest member of this formation, is very valuable to the farmer. It contains sufficient phosphate of lime diffused through its mass to render it a useful dressing to land; and seams of coprolites occur in it which are still more valuable as a manure. The rock is generally coloured with grey or red. The fossils known as "petrified mushrooms," being in reality zoophytes taking the form of a cup upon a stem, called by geologists Ventriculites, are found in this member of the formation. Others called on account of the radiating structure of their flinty substance; "Petrified Anemones," and characterized by a funnel-shaped cavity down their centre, are named Choanites; these and other sponges favour the Chalk Marl. The Cephalopoda are abundant here, the coiled Ammonites and Nautili, the uncoiling Scaphites and Hamites, the straight Baculite, and the twisted Turrilite.

Once I was nearly obtaining many of these; a well had been sunk in a marl district on the border of the Wiltshire Downs, and my reporter said there were shells and snakes of stone lying all about the yard. But, alas! ere I was able to visit

the desired spot all this precious waste had been removed, and the yard was made quite tidy again.

The Lower Chalk is most valuable for lime but less rich in fossils than the upper portion; still, the entire rock when microscopically examined, is seen to be a mass of minute fossils.

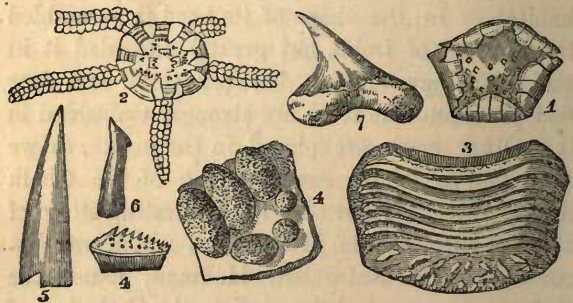
In the Upper Chalk beds, layers of flint are freely interspersed, these flints generally containing some organism. Once I saw a great display of these; crossing a field on the Chalk Downs of Wiltshire, I was surprised to see the ground nearly covered with broken flints. I inquired why the boys of the village were not employed to gather the stones off the land, and was told that the presence of the stones was preferred, for "they kept the land warm." On examining the stones I found they were nearly all hollow, while in many instances a sponge-shaped body rested loosely in the opened cavity, like a baby in a cradle (Pl. 6, fig. 6). Some of these were like brown branched twigs of oak, they were the mummies of *Spongia Ramosus;* others, more heavy in form and unbranched, belonged to another group of sponges, the Parasmilia. There are several chalk quarries about Warminster, which we were able to explore; we found shark's teeth, brachiopods, bivalves, univalves, and Sea-urchins (Pl. 6, figs. 1-5).

Professor Owen has traced some remains of pouch-bearing animals in the Upper Chalk; and

bones have been found near Maidstone pertaining to a bird resembling the albatross. Reptiles still continue to prevail, and some are new to this formation. The Mosæsaurus, or Saurian of the Meuse, was first found in the Maestricht beds; it is twenty-four feet long, its tail is short and its head large in proportion to its body; its extremities are not well known though ascertained to be of the paddle order, suggesting the water as its habitat. In the shape of its head it resembled the Monitor of India, but greatly exceeded it in size. The jaw alone is between three and four feet long, and the teeth are strongly embedded in it. Other teeth are placed in the palate, as we shall find to be the case in some of the Chalk fishes. Mrs. Wright tells an interesting story of the first specimen of Mosæsaurus which was discovered. The Naturalist, Hoffman, found the skeleton in a rock belonging to the Cathedral of Maestricht; with patient diligence he disinterred it, but as soon as he carried it home, it was claimed as the possession of the church. When, during the time of the French Revolution, the town was besieged, a contingent of savans accompanied the assailants who should secure and guard the coveted fossil; the Town Hall where it was supposed to be lodged was allowed the protection of a flag, so that during the battery no shot should endanger it. When the French had secured their prize, they did not forget to reward Hoffman.

Dr. Mantell and others have discovered remains of Ichthyosaurus and Pterodactyle in the Chalk, and also of turtles, but fishes are much more important both in species and in numbers than reptiles in this formation.

The Ganoid fishes, with their soft skeletons and external armour, appear still, and the already familiar Placoids are prominent. Here the skin



1, 2. STAR FISHES. 3, 4. PALATAL TEETH. 5, 6. SHARK'S TEETH.

is still covered with enamelled plates, though not of the firm structure that characterized those of the Ganoids; in the Placoids the skeleton is cartilaginous and perishable. Various forms of sharks belonging to this order carried on their depredations in the seas of the Chalk period. Their jaws were furnished with long, slender teeth, proceeding from a broad basis, somewhat curved inwards, and beautifully enamelled. As a further assistance in crushing their prey, the palate was

paved with flat, rounded, grooved teeth, also shining with glossy enamel; these and the spines —used as a mast to raise the sail-like fin on the back—are the only parts of these fishes that have been preserved, and these we find in quarries about Warminster, and also in one belonging to the Lower Greensand.

Of the Cycloid fishes, those whose scales are rounded and simple at the margin, composed of a horny substance but *not* enamelled, we have several representatives. The lizard-like Macropoma was one of the most abundant and most dangerous to his fellow-tenants of the waters. He was from eighteen inches to two feet long, the head measuring six inches in the smaller specimens, and the jaws armed with a number of sharp-pointed teeth. The scales were partially covered with long pimples, and the fins were furnished with bony spikes. These Cycloid fishes have bony skeletons, and many are found in excellent preservation. In the Lower Chalk the allied fish Osmeroides is present; its remains are found in great perfection, but it does not attain nearly so large a size as its lizard-like neighbour. The Osmeroides is so called, because of its likeness to the smelt. Dr. Mantell has found two or three species, and there are some good specimens to be seen in the Museum at Maidstone. Of the Ctenoid fishes, characterized by their jagged scales, we have now the first specimens. Maidstone Museum has many excellent fossils of this group, brought

from the neighbourhood of Lewes. The quarrymen called them "Johnny Dorys." They resemble perches—are short and thick, with large heads, and large scales. In length they vary from six inches to a foot, and the jaws are furnished with a band of bristle-like teeth.

Fishes of the carp, mackerel, and eel families are also found in the Chalk; and intermingled with their remains are brown nodules, supposed to be their coprolites.

The Cephalopods are abundantly present in this formation. Ammonites, Nautili, Hamites, and Baculites have left their chambered shells in plenty, and the soft rock preserves them most perfectly. Specimens of Trochus are also found, resembling the Mitre shells of our shores, of Natica, Rostellaria, Dentalium (tooth shell), and Littorina (periwinkle). Mr. Baker, of Warminster, has procured many species of these shells in his persevering explorations in that neighbourhood, and he keeps a large collection of beautifully-preserved fossils for sale. Certainly, the Chalk organisms excel all others in their beauty, the softness of the stone preserving the most delicate sculpturing intact, while its purity rivals alabaster in whiteness. A great variety of bivalves grace this formation, the Thorny Lima being perhaps the most ornamental; this shell is not only adorned with delicately-chiselled ribs, but is also defended by long spines all over the upper valve, many of

PLATE VII.—TERTIARY.

1. Megatherium. 2. Glyptodon. 3. Anoplotherium. 4. A. Gracile
5. Palæotherium. 6, 7, 8. Miocene Plants.

which are found in their original position. The Pectens occur in good number and several varieties; also oysters, some really handsome, as the Carinatus, where the wrinkles of the shell are sharply plaited. The Inoceramus a little resembles the oyster, but its shell though unequal at the sides is longer, and its wrinkles more even; it is a common fossil in the Chalk. The Brachiopods are represented by several Terebratulæ, Rhynconellæ, and Craniæ, the last distinguished by having the under valve quite flat, for the convenience of attaching itself to other bodies. Several corals and sea-worms are found in these rocks, the Pentacrinus still flourishes, and a less graceful encrinite called Marsupites makes its appearance: stemless, and enclosed in a cup formed of plates, which procures for it the name of "Cluster Stone" from the quarrymen.

The Sea-urchins form a marked feature in the contents of the Chalk cliffs. We have the Spatangus Cor-Anguinum, the "Shepherd's Crown;" the Ananchytes, or "Fairy Loaf;" the Starry Micraster, distinguished by its four double rows of tubercles, and the more decidedly heart-shaped Holaster. Beside these, we have varieties of our old friend the Cidaris, often with its clubs lying beside it, or even sometimes attached. Crabs, too, are found fossil here, allied to the Hermit crab of present seas; their bodies are not preserved, only their claws, the right claw being always the

largest: thus agreeing with the structure of the Hermit, whose body, being shell-less, has to seek refuge in the shells of other animals. The claws of the Chalk are generally found associated in a similar manner with the shells of mollusks.

Fossil plants are rare in these rocks; they consist of Algæ badly preserved, and drifted leaves as of the Dragon tree. Such are the most commonly met with fossils of those mound-like hills which extend across England under the name of Downs and Wolds. At Flamborough Head they form magnificent cliffs; and again on the South coast, as at Beachy Head, here immortalized by our best poets as the "White Cliffs of Albion." From the coast of the Isle of Wight they jut out like "needles;" but their form is owing to the effects of storms and tides, the softness of the rocks making them an easy prey to external influences.

CHAPTER XII.

TERTIARY SYSTEM.

1. Eocene.—2. Miocene.—3. Pleiocene.

"One glance—but one—
O'er the huge tombs of vanquished Time around ye,—
Mountains of ruins piled by me alone:
I did it: I smote yesterday,—to-morrow
wait to smite."

The population of the Secondary era have now in a great measure died out, leaving the stage open for new forms of animal and vegetable life, and as they appear one after another on our globe we shall recognize a growing identity with the forms living and breathing around us in the present day; development in animal and in vegetable organisms proceeds at the same well-attuned pace, and inorganic nature harmonizes in conformation and climate with its inhabitants. Horny sponges inhabit the seas in place of the living ones that have died away; only two Crinoids continue their work of sea-scavengers, and the tribe of Sea-ur-

chins dwindle in numbers. Brachiopods become very scarce, but their place is filled by hinged bivalves, and univalves appear in great numbers. Crab-like creatures increase rather than diminish, but their powers are improving, so that now they walk instead of swimming. The Ganoid fish die out and Placoids decrease, but Ctenoids and Cycloids prevail. Crocodiles become tyrants of the waters in place of the Sauroid fishes, turtles frequent the shore, and lizards abound. But the characteristic feature of the Tertiary age is its mammals, so numerous in species and gigantic in individuals. As corals and fishes were the characteristic fossils of the Primary rocks and reptiles of the Secondary, so in the Tertiary are mammals.

A general breaking-up of the beds of older formations seems to have marked the close of the Mesozoic era, from which a general alteration of the face of the earth ensued. A considerable time was occupied with these changes, so that the flints of the Chalk, being first broken into small pieces, and then rolled and re-rolled by the action of water, formed a pebbly deposit. Repeated elevations of the sea-bottom probably cut off the inhabitants of the then sea, or possibly, as Professor Ansted suggests, "a considerable tract of land was formed in an East and West direction, cutting off communication between districts not far removed in latitude, and extending, perhaps, from Asia Minor far out into the Atlantic." "All we *know*," he continues, "is the great fact of the ab-

sence of the Chalk species in the Tertiary beds, their place being supplied by new species, for the most part of very different organization."

Then, as far as we can judge from rocky annals, a rising movement took place, probably from East to West, developing itself fully in the middle of Europe, "extending thence to the western part of England, along what is now its southern coast," and elevating the East coast of the Adriatic, the Caucasus, and the Pyrenees. This movement was concluded at an early period in England, but it extended into the middle Tertiary in Europe, and much later in Asia.

We have data enough to warrant a confident assumption of a tropical climate in the Tertiary period. Exposed to the influence of heated waters, such as those of the Gulf Stream, and shut out from northern currents, the atmosphere might well become genial, and invite the presence of a tropical series of plants and animals. The clays and gravels of the London basin, and the marls and gypsum of Paris, enclose remains of Palm leaves and fruits, pods from trees of the Bean family, fragments of Mimosa, and of several kinds of Laurel, etc., many of these plants closely allied to those adorning the banks of the Ganges. Fishes of the Shark and Ray groups peopled the waters, along with Turtles and Pacyhderms, whilst Foraminifera and Infusoriæ existed in such quantities as to form beds of immense extent from their cast-off shells. Fresh-water univalves and bivalves give

testimony to inland lakes, while land-snails add their small confirmation to the witness of the mammals, that land existed with all its accessories.

Imagine England, then, with a coast deeply indented with bays, the sea tenanted by sharks, sword-fish, and their allies; cephalopods, univalve and bivalve mollusks, either floating in the deep water, or diverting themselves among the rocks; the land clothed with rich vegetation, shaded by groves of tropical trees, amongst which troops of monkeys, opossums, and squirrels gambolled; while birds and insects dwelt in their branches, and serpents coiled in the sunshine. The rivers alive with turtles and crocodiles, while huge mammals, the elephant, rhinoceros and their congeners, strode over the land.

The types of this system are called Cainozoic, or *recent life-types,* because allied to existing genera.

The Eocene, so called because its fossils exhibit the *dawn* of existing *life,* is the earliest member of the Tertiary group. Fossil trees, plants, and fruits found in the Isle of Sheppy, at the mouth of the Thames, mark the *débris* of tropical forests; seed-vessels, like those of mallows, others resembling the pods of peas, fruits allied to the cocoa-nut and pepper; wood, remains of shrubs, as the laurel, leaves of veined network allied to the maple and elm, are among the deposits there. Fan-palms, cypresses, acaciæ, hazels, and birches flourished in these forests, while various ferns, mosses, horse-tails, water-lilies, and other pond

plants lived under their shade. In the same stratum, developed near Brussels, petrified trees are found in abundance,—palms, bamboos, and poplars; some of them pierced with the Teredo in every direction; strange to relate, these Teredos smell as strongly of their native element as if thousands of years had not passed over them in their wooden burial places!

The elevation of the land previous to this Tertiary period had left certain basin-like depressions on its surface, now known as the London, Hampshire, Paris, and Isle of Wight basins. In these hollows the crushed and rolled flints, the *débris* of the chalk, and other waste were deposited; then their own forests and animal inhabitants added to the accumulation, to be disentombed in the present age; then the distant future. At first the imprisoned waters would be brackish, where the communication with the sea was not quite closed they would be salt, and under different circumstances freshwater lakes would exist, bearing lilies on their bosom, and nourishing mollusks in their depths.

The beds of London clay in the Isle of Sheppy afford fossil crabs and lobsters, whilst in the neighbourhood of London great numbers of bivalves and univalves are found. Masses of tubiferous coral are found near Kingston-on-Thames and elsewhere; Teredos are by no means uncommon. Sea-urchins still occur; oysters, cockles, arcas and nuculas, and many other bivalves are frequently met with. In the railway cutting near Highgate

I have found iron-stained specimens of Tellina and Nerita. The Fusus, Murex, Conus, Lymnea, and Planorbis represent the univalves, while the Nautilus prevents the old tribe of Cephalopods from being forgotten. The soil is here a heavy clay, stained with yellow and blue colours, and containing *Septaria*,—nodules of clay mixed with sulphur and veined by glittering spar tinged with amber; when split they exhibit curious sections, and form a kind of marble, suitable when polished for small tables, slabs, etc.; their most important use is for making Roman Cement, for which purpose they are carefully collected, especially in the neighbourhood of Harwich.

Under and about London, teeth of sharks and bones of many kinds of fishes are found, but the latter are not in good preservation; far better specimens are brought from an analogous bed on Mount Lebanon and from the Isle of Sheppy. Here the curious Sciænurus, a Ctenoid fish of the perch family, is excellently preserved, its scaly cheeks forming an easy mark of distinction. In the Eocene beds at Monte Bolca, in Italy, a remarkable family of fossil fishes are found, with a spine rising from behind the head longer than the whole body, and furnished with a sail-like fin, extending from it to the tail. A very perfect Ray-fish from Mount Lebanon has been procured and described by Sir P. Egerton; it has a smooth skin, slender tail, and numerous spines, extending in every direction. Ganoid and Placoid fishes are

still found, though in comparatively small numbers, and some of the Chimæra family.

Bones found in the London clay give proof of lizards and crocodiles pervading the waters, while turtles and tortoises (Pl. 7, fig. 2), were also present in abundance.

Animals of the serpent order related to the boa constrictor, and a few birds, are found in the London clay. In the Paris basin the remains of birds are more plentiful, and species are found resembling the quail, buzzard, owl, woodcock, and pelican.

The remains of mammals are more numerous in the Paris than in the London basin, but many species are present in both. Teeth supposed to be those of creatures allied to whales are found, though perfect remains do not occur till the Upper Tertiary strata. Thick-skinned animals resembling our pigs (Pachydermata), appear in great numbers, several genera, some containing a dozen different species, have been discovered (Pl. 7, figs. 3, 4, 5). They vary in size from that of a hog to a horse, and they have a short fleshy proboscis like a tapir. The Lophiodon, named from its crested teeth, belonged to this family; its appearance is described as "intermediate between an elephant and a pig." It ate vegetables of all kinds; but, like the hog, it could probably satisfy itself with any kind of food. The Palæotherium frequented the banks of rivers and lakes, and its remains occur in great abund-

ance in gypsum quarries near Paris. It was larger than the Lophiodon.

Of more graceful form and active habits, the Ziphodon approached the deer in elegance of contour. It resembled the gazelle, and would skim the ground along the river banks, browzing on the tender shoots and flying at the first approach of danger. The name of the tribe means *weaponless,* because their teeth are like human teeth and they have no tusks. A more common genus of the family had a form rather resembling that of the ass, but longer in the body, and with a very extensive tail, as powerful as that of the kangaroo. Another group of these animals contains animals as small as the hare, and one discovered in the London clay had an eye as full and large as the eye of that timid quadruped.

And now as the Eocene period closes, the sea-bottom in various localities becomes more and more elevated; the Wealden district becomes dry land again, shallows receive the shells of Foraminifera in multitudes, thus forming the limestone of the Apennines, and the beds of Nummulites and Miliolites.

In the South-East of England, near Brussels, and in the Paris district, river-brought mud was being deposited, while upon the land tropical forests flourished teeming with animal life, as did also the waters of the great sea. The Miocene or Middle Tertiary deposits are wanting in England,

but are well developed in the Rhine Valley, in Switzerland, Hungary, and Poland.

In the swamps of the Rhine valley dwelt the gigantic Dinotherium, an animal twenty feet in length, with a clumsy body resembling that of the hippopotamus, the only part appearing above the water would be the elephant-like head, which was armed with two drooping tusks. It fed on herbs.

Turtles and fishes are also found in the Miocene rocks. Great volcanic movements are supposed to have taken place at this period; according to Professor Ansted, it is probable that these threw up the basaltic columns of the Giant's Causeway, disjointing strata in many places, and raising the aggregated masses of Nummulites and other deposits into mountains, as in the Alps and Carpathians.

The Red Crag of Suffolk forms the first member of the Pliocene or Newer Tertiary formation; it is formed of red sand, and is ten to twenty feet deep; from the place of its development it is called Suffolk Crag. This stratum is important to agriculturists as containing great numbers of coprolites which are quarried at Felixstow. Shells abound here —Fusus, Murex, Nassa, Voluta Littorina, Cypræa, Tellina, Modiola, Patella; they might be mistaken for specimens recently thrown up on the shore, except for being somewhat coloured by the red sand.

In a higher deposit, the Norwich Crag, Mammalian bones are found in abundance, many of them allied to our familiar friends, the horse, ass, hog, deer, bison, and bull.

In the same formation the ear-bones of whales occur frequently, and in the newer Pliocene beds, according to Professor Owen, "the remains of great whales, referrible to existing genera or species, have been found in Britain."

In the Pampas rocks of South America the huge bones of the Megatherium (Pl. 7, fig. 1), have been found somewhat resembling the sloth, but larger than the largest rhinoceros; it attained a length of upwards of ten feet, but its bones were disproportionally massive. Its huge fore-feet seems to have been formed for digging up roots, and its teeth show it to have been herbivorous in its diet.

Of smaller size, but similar build, was its companion the Megalonyx; it was also remarkable for its huge claws. Here roamed the huge Mylodon, of which so fine a skeleton may be seen in the Hunterian Museum. From the nose to the end of the tail it measures eleven feet, and its bones are very massive. It was an herbivorous animal, and like the Megatherium its fore-feet seem adapted for digging and grasping, while its short thick tail and strong hind-legs suggest that it sat upright to strip the leaves from the branches.

Bears of several species mark this formation, and animals of the pouch-bearing family; bats also, and some birds—as swallows, woodpeckers, larks, cuckoos, parrots, pheasants, geese, gulls, and vultures; the eggs of some are also preserved.

Shells were abundant in these seas, and in a very great measure are the same as those of existing species.

PLATE VIII.—TERTIARY.

1. Mammoth. 2. Hippopotamus. 3. Machairodus. 4. Hyæna. 5. Bear. 6, 7. Crustaceans. 9. Fish Teeth. 10. Corals. 11—16. Shells.

Tertiary deposits of one or other of the groups are found in every quarter of the globe, but as the vegetation and animal population of the period closely approaches that of the present day, the existing differences between those of different countries were nearly as marked then as now. Page points out these analogies :—"The Tertiary Mammals of South America resemble the sloths, armadilloes, and ant-eaters of that continent; those of Australia its marsupial kangaroos and opossums; those of New Zealand, gigantic wingless birds, like the apteryx; while those of the Old World have more immediate relationship to its elephants, rhinoceroses, horses, deer, and oxen. A few genera, indeed, as the mastodon and horse, seemed to have enjoyed a wider range, fossil species being found simultaneously in Europe, Asia, and America."

Volcanic action has been busy with Tertiary deposits in the Rhine country, Scotland, Switzerland, Hungary, and Italy. The rocks of this system afford limestones, building-stone, and marble; the Sphinx is formed of Nummulitic stone, the shells standing out on her weather-worn surface, being called in the district "Pharaoh's beans." Brick, and potters' clays are produced in abundance, and a valuable kind of millstone from the Paris basin. In Devonshire, as well as in France and Germany, the deposit contains beds of lignite, or "brown coal," and fossil gum, known as amber, is found among the lignite.

CHAPTER XIII.

POST-TERTIARY SYSTEM.

"As a huge stone is sometimes seen to lie
Couched on the bald top of an eminence,
Wonder to all who do the same espy,
By what means it could thither come, and whence—
So that it seems a thing endued with sense,
Like a sea-beast crawled forth, that on a shelf
Of rock or sand reposeth—there to sun itself."

WORDSWORTH.

THE elevations which took place during the Pliocene deposition altered the Chalk rocks into the ridges of rounded hills which are so characteristic of that formation, the Hampshire and London basins lying as low marsh ground between them. A succeeding period, called by some authors Pleistocene, or most recent, because its fossils are with very few exceptions identical with the organisms of the present day, witnessed a few

further changes; the freshwater lake, now marked by the New Forest of Hampshire becoming separated from the London basin, and the line of Chalk cliffs being severed by water currents, so as to make of a portion of the mainland the Isle of Wight.

This Post-Tertiary epoch is marked by deposit of three kinds:—1st, Fossiliferous clays; 2nd, Cavern contents; 3rd, Drift formation. On the South-East coast of Yorkshire, between the mouth of the Humber and the higher ground towards Bridlington, is a wide tract of low land, occasionally rising to the height of from 50 to 140 feet, as at Dimlington, but generally forming low cliffs as a sea boundary. Upon this tract the sea is still encroaching, and on old maps we find villages marked as "washed away by the sea." Professor Philips mentions one village which had almost disappeared during his own term of observation; and as we recede from the Humber we find a pebbly deposit pervades the coast-line, then remains of freshwater mollusks and plants mingle with the gravel, and in hollows in the cliffs clay is found with freshwater mussels, surmounted by a growth of peat containing horns of deer, and, in one instance, a canoe. Shell marl containing numerous species of present shells succeeds, and then we have gravel and pebbles again till we approach Bridlington. This district of Holderness was a sea bed in the Post-Tertiary age. At Bridlington the

cliffs contain both freshwater and marine fossils belonging to the Pliocene period.

A deposit of this nature occurs in the Clyde district, also in the region of the Forth. The fossils of these are of existing species of shells, with bones of mammals, in many instances identical with present races.

But in this period grand animals trod the globe in hundreds, who have left no descendants, though their skeletons are entombed in thousands. Not only do we find these in the sands of the Pampas, but in sepulchres of wonderful formation, hewn out of rocks by the patient chisel of nature. We cannot call these sepulchres rude, for they are adorned with forms of stalactite and stalagmite, rivalling the most exquisite alabaster in purity, and of designs unique for quaintness and grandeur. One of these caverns was discovered among the Mendip Hills, near the village called Wookey Hole. Here were found teeth and bones of hyænas, of Irish elk, of mammoth (Pl. 8, fig. 1), wolf, fox, horse, and cat. Many of the bones were splintered and broken, as if the hyænas had been eating them. The absence of any remains of hippopotamus, or water-rats, indicates that this cave was not very near water; it contained also a flint spear-head. These kind of caverns abound in the Carboniferous limestone of Derbyshire, Yorkshire, and Devon; and also in Italy, Greece, and America; while the Oolitic limestone of Franconia is equally favourable to their formation. One of the

most important of our British Drift caverns is that of Kirkdale, near Kirkby Moorside, in Yorkshire; and the account of it we have from no less reliable a pen than that of the late Dr. Buckland. It was strewed over like a dog-kennel with hundreds of teeth and quantities of splintered bones, the remains of elephants, rhinoceroses, hyænas, etc. The teeth marks in the bones matched exactly with the teeth of hyænas, from which circumstance Dr. Buckland drew the inference that the cave had been for a long period a den of hyænas, and that they had dragged thither the bodies of the other animals for their food. Quantities of coprolites found mingled with the bones were shown to the keeper of a menagerie, and he recognized them as the same in kind as that of the hyænas under his charge. Dr. Buckland was of opinion that the bones had been long in accumulating, first one layer and then another having become invested with the stalagmite cement. After the tenants were destroyed, mud and water overflowed the cave, forming a fresh floor, and upon that again stalagmite accumulated. Some years after Dr. Buckland published his account of the Kirkdale cave, Mr. Bristow, Mr. Pengelly, and Dr. Falconer determined to search a similar cavern at Brixham, in Devon. This cave was partly covered with stalagmite, and under it lay a stratum of loam answering to the clay of the Kirkdale one. Many animal remains were found here, as the cavern bear, Irish elk, reindeer, etc.; entangled

in the horns of the latter were rude sculptured flints, such as an uncivilized race might form for lance or arrow heads. Dr. Falconer, taking a tour in Sicily about this time, examined a similar cave there, and found upon its roof a mass of conglomerate formed of teeth of animals, broken bones, carbon, snail-shells, and flint and agate knives, "resembling obsidian knives from Mexico," as Professor Ansted tells us. The bones were the same as those found in English caves; the whole must have drifted in in calm water, and filled the cave, stalagmite acting as cement; afterwards the water must have swept much of it away, and the position of the rock been upheaved.

Many other bone caverns are well known, but those already described may stand as descriptive of all. England has them in Derbyshire, near Torquay, Plymouth, Denbigh, and Swansea. Several occur in the Harz mountains, and the Jura range is famous for a notable string of them,—Gaileureuth, Wunderhohle, Rabenstein, etc. Hungary, France, Sardinia, and Dalmatia also boast Drift caverns.

Bones of many animals occur in all these, and some are more local in their habitat. The first father of the elephant (Pl. 8, fig. 1), ranged at this period in England, accompanied by his ally the huge mastodon. The hippopotamus (Pl. 8, fig. 2), made his way through the waters; as did also the otter and beaver. This was also the period of the rhinoceros, tapir, ancient pig, an-

cient horse, Irish elk, reindeer, antelope, bear (Pl. 8, fig. 5), hog, lion, several kinds of hyæna (Pl. 8, fig. 4), wolf, fox, polecat, and weasel. The massive Megalonyx and Megatherium flourished in this age, along with our familiar rats, hares, and rabbits.

Thus the earth was thronged with animals, who sought their food by day and by night, and the sea was full of life. What sudden convulsion was it that entombed this teeming fauna, enclosing the savage beast of prey in their dens along with the victims of their greed?

Water, that great agent in earthly change, will not alone account for the traces of violence at this period; for the agency that fossilized the animals in their dens transported vast boulders, of many tons weight, from great distances. Masses of granite from the Scottish Highlands are thus scattered over the plains of Mid-Lothian, and similar blocks from the Cumberland hills spread over the moors of Yorks., while huge boulders from Lapland and Finland repose on the plains of Russia, and granites from Normandy lie on the flats of Denmark. Add to this, that the surface of many of these boulders is marked with scratchings and groovings as if they had rubbed forcibly over one another, while similar markings deface the surface of the rocks on which they repose; and we are led to ascribe the influence to ice-floes, the only agency that could transport the massive waste from distant rocks.

Thus we have every reason to suppose that a cold period succeeded to the genial climate of the Tertiary Ages, and that Arctic conditions prevailed during its continuance, breaking down the rocks by the power of intense frosts, and sending the eroded material upon avalanches and ice-floes in various directions, as the current of that stormy sea should drift them. These icy waters deposited shells of Arctic type in the valley of the Clyde and elsewhere, leaving their traces to the present time in Arctic plants, and, eddying here and there, ground beds of gravel from the waste of adjacent rocks, thus depositing many a water-worn fossil in pits and hollows to the perplexity of young geologists, as we can bear witness, who found our first geological difficulties in the defaced gryphites and corals on the gravel walks at Leamington.

In the beds of clay or sand deposited by the retreating waters of this great glacial sea, the most wonderful phenomena are those rudely-chiselled implements, such as arrow-heads and knives, formed of flint or other stone, and *evidently the result of human contrivance.* These manufactured articles include chips of flint, granite, jade, serpentine, jaspar, and basalt; some are mere flakes, apparently intended for knives or arrow-heads; some are pointed at the apex, and blunt at the base, possibly for lance-heads; others are oval, and sharp all round, probably for sling-stones.

The English geologists having found such things in the Mendip Cave and elsewhere, began to attach some credit to M. Boucher de Perthes, who had announced the discovery of similar articles in pre-glacial deposits at Abbeville. He had indeed written a book on the subject, which, however, had attracted no attention in England; Mr. Prestwich, accordingly, went to examine the beds reported to contain the flints, at Acheul, near Amiens.

He found first, a bed of brown brick earth containing old tombs; under this, whitish marl, containing recent bones and shells and teeth; and lastly, a thick deposit of flint gravel with some shells and bones of elephant, ox, horse, and deer, and with them a considerable number of worked flints. Near Abbeville he found a still more interesting section-gravel, containing bones of deer, horses, mammoths, and rhinoceroses, and shells both marine and freshwater—all these mingled with flakes of flint, flint knives, and flint hatchets; all stained, like the rolled pebbles, with the gravel among which they lay. Geologists class these beds with the Tertiaries of Croydon and the neighbourhood of London.

The gravel beds formed here and there over the face of the land, separate from or accompanied by the masses characterized as boulders, belong to the same formation as that of the Clyde Valley, of the Alps, and of South America and Australia.

In the last-named country are found the Wellington Valley caves, containing the bones of a kangaroo, the skull of which, according to Professor Owen, exceeds that of an ox in size. Mr. Wood, in his recent work on the geology of Australia, gives an account of a petrified man found in one of these caves! A native, mortally wounded by the settlers, as a retribution for sheep-stealing, crawled into the furthest recess of the Blanche Cave and there died, not many years ago. By constant dripping of lime-water from the roof of the cave, his body soon became encrusted with stalagmite, and literally cased in a stony shroud. For some time this "petrified man" was the lion of the district, till an enterprising showman stole him for a European exhibition.

The Kunkur of India, occupying a large tract between Guzerat and Delhi, and not only covering the low ground, but reposing under the surface soil of the raised plateaux of Central India, and, in some cases deposited upon hills 2000 or 3000 feet above the level of the sea, is another of the great glacial deposits.

In our own country, we must picture all Worcestershire and Gloucestershire under this glacial sea, whilst glaciers floated among the hills of Scotland and Wales. In those days Snowden was a naked peak, and the hills of Derbyshire and Yorkshire were a protecting fringe to Middle England, catching the ice-drifts and suffering their load to accumulate round their feet.

CHAPTER XIV.

POST-GLACIAL SYSTEM.

RAISED BEACHES.—RIVER DELTAS.—TUFA AND PEAT.

"See how the torrent rolls the golden sand
From the high ridges to the lower ground,
The lofty lines abound with endless store
Of mineral treasure and metallic ore."

LONG ages passed onwards, and in due time the floods rolled back, and the land gradually arose—what was the sea-bed becoming dry ground. Still many of our rivers were of undue extent—quite arms of the sea—as the Severn, in which instance the beds of shingle, and the raised beaches near Worcester and at Bewdley, show that where the river now winds flowed the waters of an estuary. Shingle banks along the Wye, near Hereford, indicate elevated beaches more than a

mile apart. This may be called the Great River or Fluviatile period, when many of our valleys were freshwater lakes and marshes. In these raised beaches a few fossil shells are found belonging to existing genera. Shells, marls and gravels in various parts of England are contemporary with the raised beaches. In New Zealand the river drift contains bones of Dinornis, one of their huge wingless birds: the newer gold gravels of California and Australia belong to this period; the cotton soil of India, and the black-earth of Aralo Caspian, the loess of the Rhine valley and the volcanic tuff of Naples are all deposits of this formation.

Following the plan of one of the most lucid exponents of geological facts, Mr. Page, we may consider this deposit with reference to the various agencies employed in its formation—as river, lake, and sea, chemical, volcanic, and organic force.

Rivers in cutting their way through the country, especially during oft-recurring floods, carry along with them the waste from the rocks, the soil from the inundated hill-side, and all loose matter which comes within their influence. This is deposited on the low lands as the waters retire, and thus the rich meadows in our valleys and plains have been formed. Bones of extinct animals have been found among such alluvial deposits, scattered among the mass of the various level terraces marking the subsidence of ancient floods. Thus

the gold-laden quartz *débris* has been washed into the sands of California and Australia; and the dark waste of the Cornish rocks become deposits from whence *stream-tin* is procured.

But the principal mass of river waste generally accumulates near the mouth, thus forming the triangular patch of alluvial deposit familiarly known as a *delta*. Many of these deltas are famous for their extent, as those of the Mississippi, the Amazon, the Niger, and the Ganges; but the formation may be observed in nearly every river's mouth. Organisms of various natures are found in these deltas; from that of the Rhine I have disinterred numerous land and freshwater shells, whilst the delta of the Ganges is prolific in fossil palms and ferns and bones of mammals. No delta is so interesting as that of the Nile, which has recently been subjected to the most careful scrutiny. By a close observation of the accumulation around the base of pillars of known date, it has been ascertained that the deposit increases at the rate of about four inches in a century. In order to examine the descending order of the mud, pits have been dug in various directions about Memphis and in other localities; here shells have been found and fragments of burnt brick and coarse porcelain, at a depth of thirty feet. To what a distance does this throw the first efforts of the human race! The geologist more than any other man must see con-

stant reason to exclaim "Great and marvellous are thy ways, Lord God Almighty!" and "That which I know not teach Thou me."

Lake deposits are found either in present lakes, or where lakes have been. Large tracts in the prairies and pampas of America are ascribed to this agency; shell, clay, and marl are thus deposited. Shell-marl is composed of lime and fresh-water shells; clay-marl of mud and lime; sometimes it becomes solid by the percolation of lime-charged water, and then it is rock-marl. It is useful for agricultural purposes. Marine deposits are classed as sandbanks, sand and shingle drift, and ancient beaches. By dredging it is ascertained that sandbanks are accumulating in the sea bottom, fed by organic and other matter, transported by ocean currents, and ready in case of the rising of the bed of the sea to form rocks such as our limestones.

The sand and shingle drifts are generally formed of fine sands and powdered shells, and contain both marine and terrestrial organisms. The shingle accumulations heaped up on the shore by the united action of waves and tides, lying on exposed beaches not far from the level of high-water, belong to the same class. These are developed to a great extent on the shores of Arctic seas, the gravel shingle and boulders thus heaped up only needing a cement to "rival the Old Red conglomerate" in thickness. There is also a boulder

ridge at Northam, in Devonshire, which testifies the power of existing marine force.

The "ancient beaches" are raised from ten to sixty feet above the present sea-level; sometimes they present the usual aspect of the sea-beach, at other times they are a mere terrace-road along a hill-side, as the "Parallel Roads" of Glen Ray. Nearly all the shells pervading these beaches are such as now strew the seashore.

Submarine forests may be referred to the same class of agencies, marking depressions in the coast line as the others mark elevations. They exist in the Frith of Forth, near the mouths of the Humber and Mersey, at Bournemouth, and near Hastings. This last consists of dark-coloured clay, with stumps and trunks of trees in a semi-fossil state; it is only laid bare at low tide. It may be taken as an example of its class.

Chemical deposits include Tuff, Stalactite, and Travertine. Calc-tuff is formed by waters charged with lime,—we may take the dropping-well at Knaresbro' as an example, where any object suspended within reach of its drippings becomes speedily encrusted with lime, or "petrified," as it is termed in the district. When the lime separates merely from exposure to the air, and without coming in contact with any object *en route*, it is deposited on the ground, and forms a compact mass of crystalline texture, known to geologists as calc-sinter. The formation of stalagmites and stalactites by the lime-water percolating through

cavern roofs and walls, we are already familiar with. Travertine is a similar formation, abundantly formed by the waters of the Anio, near Rome; it is a compact, hard, semi-crystalline rock.

There are silicious deposits from springs, as well as calcareous ones, and around waters charged with this mineral we find the mosses and grasses encrusted with flint. Salt also forms in masses round saline springs.

Volcanic agency has been developed in recent ages, and is still at work, effecting gradual elevations and depressions—by an earthquake raising vast districts, proportionably sinking others, or tearing or cracking the strata in every direction; or by pouring from gaping craters floods of melted matter extensive enough to form a mountain or raise a plain in a few days.

Organic accumulations occur,—as peat-mosses, coral reefs, and shell beds. Jungle growth, being the same in nature, may be included in the peat formation. The importance of such agency in affecting the general surface of the globe may be illustrated by a picture of Dr. Richardson in writing of Canadian rivers:—"As the trees retain their roots, which are often loaded with earth and stones, they readily sink, and, accumulating in the eddies, form shoals, which ultimately augment into islands. A thicket of small willows covers the newly-formed islands as soon as they appear above water, and their fibrous roots serve to bind the whole more firmly together. Sections of these islands are annually made by the river, assisted by the frost, and it is interesting to study the diversity

of appearance they present, according to their different ages. The trunks decay until they are converted into a blackish-brown substance resembling peat, and layers of this often alternate with layers of sand and clay, the whole being penetrated by the long fibrous roots of the willows." As the accumulations of a larger type of vegetation characterize tropical climes, so the *peat* is peculiar to cold or temperate regions. It is formed by the annual growth and decay of mosses, reeds, and other water plants. These give out tannin during the process of their decay, which acts as a preservative to the other matter accidentally embedded with the typical vegetation. Thus the bog-wood of Ireland is preserved, while at the same time it is blackened by the impregnation of iron; and bones and horns, as well as manufactured articles —as canoes—are also found amongst accumulations of peat. But the most important of its deposits is the bog-iron-ore, which forms a thin cake, and evidently results from the oxides of iron held in solution by the waters of the morass, and which have been carried thither by springs and small streams. Peat-moss accumulates quickly in stagnant water, gradually filling up hollows, and at last forming land safe for the foot to traverse. It occurs in all stages of consolidation, "from the loose fibrous turf of the previous summer to the compact, lignite-looking peat, formed thousands of years ago." It is found on bogs, moors, and hills, —proverbially valuable as fuel. "Geologically,"

as Mr. Page says, in his "Hand Book," "it may be considered as the youngest member of a series, of which lignite, coal and anthracite are earlier and more intensified mineralizations. Mineralogically it constitutes the latest and least metamorphosed of the coal family."

Coral reefs are to the Pacific ocean what flood-borne trees are to the Canadian rivers,—forming islands in the midst of the waters. Coral is almost pure carbonate of lime, soft when first deposited by the zoophyte, but gradually becoming hard as stone. Shells coming in contact with the coral during its formation quickly become embedded, thus increasing the mass. This wall of coral rises by invisible degrees to the surface, the stony walls withstanding the beating of the waves, and forming natural break-waters and sea-walls to extensive lines of coast. In full sea they build their fortress in a ring of a few hundred yards wide, measuring from one side to the other from one to thirty miles. Gradually this circular island, or Atoll, appears above high-water mark, and becomes the habitat of plants and trees, a beach of glittering white sand intervening between the vegetation and the sea. An inner beach encloses the still waters of a shallow lagoon, resting for the most part on white sand, presenting a vivid green hue in the sunshine.

Shell beds are formed in wide areas on some coasts, and may be considered worthy of mention as organic agents. The shells of Foraminifera, or the shields of Infusoriæ, form extensive masses of

rock and earth; accumulations of this nature are blocking up the harbour of Wismar, and increasing in the bed of the Nile. The Berg-mahl of Lapland, the edible clay of Brazil, and the white earth of the American Indians, used by the aborigines of the different districts to mingle with their food when that is too limited to appease their hunger, belong to this class.

Thus we see that the agencies of change which our present eyes can behold and test, are precisely the same as those that have formed the most ancient rocks;—wild sea-waves breaking down and throwing up heaps of waste, organic and inorganic, all crushed together as in the Silurian, Devonian, and other periods; elevated or evaporated seas and lakes leaving their inhabitants suffocated in the mud, as in the Lias, Wealden, and London clay: deep torrents bearing down their load of vegetable and animal *débris*, and depositing them in deltas as in Carboniferous and Oolitic Ages; chemical forces, cementing by lime or silica, or forming beds of salt, as in the Carboniferous, Permian, and New Red formations; volcanic movements rising and depressing, breaking up plains and upheaving mountains, as with the Chalk downs, the Trap rocks, and the numerous "faults" in strata; or the organic accumulations, as the Coal measures, forest Marble, and Nummulitic limestone. "The thing which hath been, it is that which shall be, and there is no new thing under the sun."

CHAPTER XV.

CONCLUSION.

"In the coming time it will be seen by all what a noble vestibule the old Geologic Ages form to that human period in which moral responsibility first began upon earth, and a creature destined to immortality anticipated an eternal hereafter."

HUGH MILLER.

IN our brief attempt at tracing the history of our planet, we have endeavoured to decipher the records of the Book of Nature. We have looked back to the darkness of chaos, and heard the fiat of creation go forth; we have pictured that "beginning," when God "appointed the foundations of the earth," when the Word (Logos) created all the hosts of heaven, and the Spirit of God brooded on the face of the waters. Then began that march of creative wonders which the

science of Geology bends all its powers to understand. The seas of Siluria teeming with the life, called forth by God's Spirit; every minutest creature marvellously made, and fitted for its sphere, each a triumph of Divine wisdom; the complicated eye of the Trilobite rejoicing in the newly created light, the sightless Graptolite and Brachiopod secure in the darkened depths of the ocean. The separating of land and sea, marking the Devonian and Carboniferous periods; the prevalence, first of the ocean denizens, the marvellously guarded Ganoid fishes, their enamelled scales protecting them from the severe cold of those seas; then of the dense and luxuriant vegetation of the Coal measures following in quick succession upon the separation of dry land; here surely we tracc wisdom in unison with love: in that dawn of creation the Father of all furnishes a storehouse with the means of comfort and ingenuity for the favoured children of His choice—children not yet in existence, nor to be called to life for vast ages yet to come. On moves the advancing army of wonders; God orders His agencies by fixed laws, dividing times and seasons, days and nights; the sea flows over the Coal forests, and its sediment seals up the treasure caves; Corals rise, and Shell-fish move over the areas of the gigantic vegetation, severe cold succeeding to the tropic climate of the Carboniferous period. The season of ancient life is now past, and that of

Secondary life sets in; the level of the land changes, old elevations sink and new ones rise; shell-fish abound in the sea, and reptiles wander on the shores; while marsh plants, and pine-like trees adorn the land. Vast supplies of Salt are stored in dried-up lakes, and arms of the sea; masses of Rock are formed, and the work of Creation goes forward.

The Age of Reptiles comes next in order, some like "great whales" carrying devastation through the waters; and others, as the Pterodactyle, with power to "fly above the earth in the open firmament of heaven." These Oolitic seas were teeming with life, from the plant animals to the reptiles of the most complex structure; each creature exactly adapted in its minutest organism for its place and habits. Quiet seas immerse once more the land where the reptiles have been wandering; myriads upon myriads of microscopic creatures live, and die, and deposit their minute shells; and then the bosom of mother earth heaves again, and the bed of ocean becomes a range of rounded hills. Still the march presses onwards; Secondary life is past, following the steps of ancient life, and recent creations appear upon the stage. Great Mammals stalk on earth's surface, "beasts of all kinds, and cattle, and every kind of creeping thing," abound in this era; and birds inhabit the trees; the fields are full of vegetation; a tropical climate encourages

luxuriant growth; the waste of past ages is gathered up with care, mountain masses are formed of the cases of dead Foraminifers, deep hollows are filled in with animal and vegetable remains, and the order of life seems only to want its head. Then comes a widely desolating flood. Masses of ice ride upon its waters, stranding upon hill tops, and grating over them, marking them with grooves and scratches. On pours the flood, enclosing the wild beasts and their prey, and immuring them together in their dens; carrying destruction everywhere. Long the waters reigned pre-eminent, but at last they abate. The ice-floes remain stranded on the hills or sandbanks, where they melt away, and deposit their strange load, sometimes of shells, or gravel: but occasionally of vast boulders. The earth becomes dry, and gradually assumes its present form; God, ever the Creator, peoples it afresh with bird and beast, vast rivers drain off the water from the saturated land, and gradually dwindle to a moderate size, and the earth stands forth as we see it now. God crowns His work with His most complex creation; He makes man "in His own image," and gives all His other creatures into his hands. For him the Father has long been preparing a dominion, for him He has been storing i with the precious things of the everlasting hills; for his sake He has undertaken the work of creation, and planned the higher and

more awful work of redemption; and for him He has yet in store gifts more glorious than ear hath heard, or eye seen, or human heart conceived.

To this favoured race is given the records of the past in the book of Nature, and the teaching of the Spirit in the book of Revelation. Surely it behoves him to read the one and the other, with diligence and loving obedience, eager to trace the work of God, and to learn the will of God. Surely it is his wisdom, as well as his duty, when he finds any seeming variance between these records, humbly to ask for Divine teaching, and meekly to wait God's time to give it—not like a brutal slave to ignorance to exclaim, "I don't understand this, therefore God is not true." We are children of the Father by creation, doubly so by redemption; as children let us love and learn, and the childlike love will preclude unbelief.

THE END.

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