Geological stories : a series of autobiographies in chronological order

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The Story of A Piece of Limestone.

" Millions on millions thus, from age to age,
With simplest skill and toil unweariable,
No moment and no movement unimproved,
Laid line on line, on terrace terrace spread,
To swell the heightening, brightening, gradual mound,
By marvellous structure climbing toward the day.
Each wrought alone, yet altogether wrought
Unconscious, not unworthy instruments,
By which a hand invisible was rearing
A new creation in the secret deep.
Omnipotence wrought in them, with them, by them ;
Hence what Omnipotence alone could do,
Worms did. * * * * *
Slime their material, but the slime was turned
To adamant by their petrific touch ;
Frail were their frames, ephemeral their lives
Their masonry imperishable. All
Life's needful functions, food, exertion, rest,
By nice economy of Providence
Were ever ruled to carry on the work
Which out of water brought forth solid rock."

MONTGOMERY'S *Pelican Island*.

I AM elected as spokesman for a common and well-known mineral, which is abundant in every geological formation. Our age, therefore, varies as greatly as it is possible for mundane time to allow. Chemically, our composition is always pretty much the same, being merely carbonate of lime.

In all the rock formations we are further distinguished from the sandstones, shales, and conglomerates, by our being almost wholly of *vital* origin, that is, formed through the agency of living beings ; whereas the other rocks I have mentioned are the result of *mechanical* forces, wearing down and triturating pre-existing rocks, and then redepositing the *débris* along old sea-bottoms. In consequence of this difference, the geologist finds in us by far the greater number of those organic remains, especially of marine animals, by whose aid he is enabled to sketch forth the development of the world's great life-plan.

As a rule, all limestones have been deposited, as fine calcareous ooze, away out in deeper water ; consequently the circumstances have been doubly favourable for the preservation of any animals which might have died and become entombed in this limy mud.

The more boisterous conditions which prevailed in the shallower waters, where coarse sands and conglomerates were formed, prohibited such favourable preservation. At the same time, with the exception of what are known as freshwater limestones (which bear a very small percentage to the other rocks of the earth's crust), I must acknowledge that the sandstones afford most valuable evidence of the *terrestrial* animals. This, as might be expected, is

mainly owing to the fact that the latter were formed nearer to the shore, so that carcasses of land animals accidently drowned or carried into the sea by rivers watering large islands or continents where they lived, would sink to the bottom, and be buried up in coast deposits ; whilst the sandstone and shale formations testify to the long-continued wear-and tear of the solid land by meteorological agencies. Therefore, the limestones bear out the idea of our planet's antiquity, by suggesting the immense lapse of time which must have occurred whilst simple and lowly animal functions were elaborating the greater proportion of all the limestone rocks.

But I intend to let each of these speak for itself. They are of age, ask them ! Each contains its own suite of organic remains, the extinct creatures which lived and died whilst the limestone mass was slowly accumulating as calcareous ooze. They are tombs of the forgotten dead—stony scrolls, written within and without.

I myself belong to that most interesting geological formation known as the Silurian. Away in the heart of the " Black Country," where no less than thirty feet of solid coal abut against their flanks, you may see cropping up an irregular and continuous ridge of limestone hills. It is thence I am derived. You may gather some idea of the forces which slowly upheaved these strata by seeing the steep angle at which they lie : a little more and they would have been quite perpendicular. But this upheaval was not violent or sudden ; on the contrary, I distinctly remember its operating through long-continued ages subsequent to the Silurian period. The process was so slow as to be almost imperceptible, for Nature knows little or nothing of those violent cataclysms which have been so foolishly ascribed to her ! Examine the steep flanks of the Wren's Nest, near Dudley. There is hardly a space of a pin's point which is not occupied by the remains of some creature in which the breath of life was enjoyed countless millions of years ago !

You strike the solid rock with your hammer, and immediately the percussion liberates a heavy sulphuretted odour, which tells of the old animal oils in which the limestone is steeped. The very hardness of these rocks is more or less indebted to the same organic cause. I am told that when sculptors, now-a-days, wish to harden their plaster-of-Paris casts, they do so by boiling them in oil. The principle is the same with most limestone rocks of every age. They are steeped, saturated in animal oils ; nay, in many places across the Atlantic, where these old Silurian limestones and shales lie so deep down as to be within the action of the earth's internal heat, these oils have been distilled out of the rocks, and have followed the ordinary habits of fluids. It is by sinking through the over-lying masses that these oil-springs are reached, and the valued liquor comes bubbling to the surface. Well does it deserve its common name of *Petroleum*—" rock-oil."

But few people imagine, when its brilliant light is illuminating their comfortable homes, that they are indebted to distilled *Trilobites* for the luxury ! Here is another form of that grand law of correlation of physical force. The ancient Silurian sunlight furnished the means of vitality to the creatures which then enjoyed life. It was stored up in their tissues, and given forth in their buoyant gambols and locomotive powers. And when they died, what remained in their diminutive bodies decomposed, passed into other chemical forms, was preserved until our own day when men unlock this ancient sunlight from its oleaginous condition, and turn it to direct heating and lighting account ! Fancy sunlight bottled up in the form of trilobites and mollusca ! No wonder these should present such stony and petrified appearances, when all the animal oils have been so completely drained out of them.

How long these Wenlock limestones (for that is the name by which this section of the Silurian formation is known), how long, I say, it is since these limestones were upheaved and exposed to the action of the weather, I cannot say. Their hardness, as I have already mentioned, is most intense ; but the wear-and-tear of the atmosphere has been such as to cause the fossils to stand out in relief ; and a strange sight, therefore, is the exposed surface of

the limestone slabs. The eye is bewildered by the number and variety of organic remains, each standing forth from the fine limy mud in which it was originally enclosed. Little or no vegetation grows on this bare limestone surface ; the latter is too impenetrable to yield a foothold ; and so the geologist has it all to himself. Heads and tails of *Trilobites*, so plentifully dispersed that they immediately stamp the Silurian age of the rock, lie commingled with brachiopodous shells, worm-tubes, sea-mats, chain-corals, and encrinite stems. You require no prompter to remind you of the exuberance of animal marine life in this distant epoch, and yet the Silurian period immediately succeeds the Cambrian, about which my distant relative, the Piece of Slate, gave you an account some time ago.

Whilst the limy mud—which subsequently became hardened into solid rock, and then upheaved into its present condition—was being slowly formed in deeper water, nearer to the shore there were deposits of a different nature going on : these consisted of muds poured into the sea by rivers, or wasted by tidal and current action from old coast-lines ; gradually, therefore, the limy deposits passed into the muddy ones, so that the line of junction was almost imperceptible. Occasionally the fine mud was carried further seawards than usual, and then a thin layer of argillaceous matter was thrown down over the limy material. This accounts for the frequent alternations of limestone bands and argillaceous shales which you have doubtless seen in every section of Silurian strata.

At various epochs during the immensely long period which elapsed whilst these beds were forming, alterations of the sea-bottom took place ; the area where limy deposits had been forming became shallow, so that clay or mud began to accumulate over the same spot ; or, the sea-bottom became deeper, and, in that case, calcareous or limy material slowly formed where mud had previously been accumulating. Occasionally, perhaps, the sea became so shallow that shingle-beds were strewn over the area where both lime and mud had been collecting. My hearers can readily understand operations like these ; they are still going on over various parts of the earth’s surface ; but the time of observation has not been extensive enough to see what they can effect. Only that simple element of time is required—and our planet is changed as by the will of some powerful magician ! And, for my own part, I do not see why the timid, unconceding spirits of modern times should begrude *time* to the geologist, any more than they do *distance* to the astronomer !

The various strata which vertically succeed each other in the Silurian formation plainly indicate the geographical changes which affected these ancient seas ; and, at the same time, imply the vast lapse of time during which they were brought about. Suffice it to say, this Silurian formation, with its enclosed strata, attains a total thickness of no less than twenty-six thousand feet !

Leaving my junior brethren to speak for themselves when their turn comes, let me try and remember some of the physical circumstances which marked the epoch of my own birth. First of all, what a different geography marked the surface of the globe then from what there is at present ! I believe there was a much wider extension of sea than there is even now, when it extends over more than two-thirds of the earth’s surface ; and, owing to there having been fewer disturbances at that time, the sea was more equable in depth ; whilst, at the same time, the dry land was less distinguished by mountain-chains. In consequence of the equable depth (or nearly so) of the sea, and of the similar climature which the entire surface of the world seemed to have enjoyed alike, there was less difference in the animals and plants of various geographical zones ; but this principle was in existence, although nothing like so broadly developed as at present.

The Silurian limestones of America, Asia, and Europe differ very little in their general *facies* of organic remains. You have no difficulty in recognizing the old features which struck you when examining the Dudley strata ; but when more minutely studied, the naturalist

makes out certain " colonies," caused doubtless by difference of geographical circumstances. As the time passed away during which the great sequence of beds belonging to the Silurian formation were being elaborated, other changes took place in organic life. The most marked feature was that of a progression from lower to higher types. Species multiplied, and the general total of life-forms became more varied and less cosmopolitan.

The lowest beds of my parent formation go by the name of Llandeilo Flags, so named from the locality in North Wales where the typical section may be studied. They are, as their name implies, strata of flaggy sandstone, much worked for commercial purposes. There is a considerable quantity of limy matter in their composition, and this gives them a peculiar indurability. Interstratified with the beds of this deposit are immense layers of ancient volcanic matter,—basalts or tuffs : these flowed over the old sea-bottoms, when ejected from submarine volcanoes, or volcanoes situated near to the coast, as we find they usually are now-a-days. The ashes or tuffs were carried by the winds, and the ancient seas had their surfaces thickly strewn with cinders for hundreds of miles ; these sank to the bottom, and alternated with the regular shore deposits. Succeeding the Llandeilo Flags, we have another division, known as the Bala Limestone, also named from a locality : it has interstratified with it beds of sandstone, slates, and volcanic rocks again, which were doubtless strewn over the old sea-bottoms just like those already mentioned. The Caradoc Sandstones, named from their locality in Shropshire, containing also shelly sandstones, with soft shales and conglomerates, lie above the Bala Limestone, and complete what geologists have termed the " Lower Silurian Rocks." They differ, as a whole, in Great Britain, from their comprising such a huge bulk of strata of igneous or volcanic origin. In some places these are actually thicker than the rocks of sedimentary origin. What a stormy, restless epoch was that ! The old sea-bottom was subjected to shocks and volcanic over-flow more intense than those in the neighbourhood of Iceland, where the Skaptar-jokul is quivering with suppressed rage and superfluous power ! Then, again, these Lower Silurian rocks have neither so abundant, nor so highly organized a fauna as the rocks of later date.

Let me mention the next in order, before I give you my personal recollections of the extinct creatures you find imbedded in these rocks as fossils. The " Middle Silurian" strata commence with the Llandovery slates (another localism) ; after which you have the May Hill sandstones (about which not a few geologists quarrelled some years ago) and the Tarannon shales ; altogether, this series is about two thousand feet in thickness, the Lower Silurian beds I have described being upwards of nineteen thousand feet thick. Next come the uppermost beds (to which I personally belong), known as the " Upper Silurians," and which attain a total vertical thickness of nearly five thousand feet. They include several deposits of minor importance ; such as the Woolhope beds and the Wenlock limestones and shales, completing what is known as the " Wenlock Group." Then succeed the Ludlow beds, the Aymestry limestones, and the Downton sandstones, in the latter of which is found a bed composed of scarcely anything else than the bones, teeth, and scales of small fishes, belonging to the placoid and ganoid orders. It is in these soft shales you find the fossils so well preserved. The shells, although they have been extinct for unknown millions of years, still retain their beautiful iridescent nacre, which, however, soon decomposes by atmospherical influence.

So much, for the " stratigraphy" of this most interesting geological formation ! At the forms of life which swarmed the seas of this distant epoch I cannot do more than merely glance. I have mentioned that, generally speaking, there was a progression. This is true only of the advance in the main, for, during the earlier portions of the Silurian period, huge *Orthoceratites* abounded, and these are among the highest classes of the mollusca. The muddy sea-bottoms swarmed with " sea-pens," now known as *Graptolites*, allied to the little Corallines so plentiful in modern seas. The chief difference between them being that the former were free and unattached, whereas the latter always adhere to some other body. But, of all forms of life, those of the Trilobite family were most abundant. Several hundred species are known to belong to the Silurian formation alone. They were crustaceans, allied to the

King Crab [1] of the Moluccas, and at that time represented the lobsters and crabs of the present day. This is a group which has always been noted for its aberrant types. Like other Crustacea, the Trilobites underwent metamorphoses or larval changes. So well do the old rocks tell their story of ancient life, that the geologist has traced the metamorphoses of Trilobites through no less than twenty different stages, from the egg to the adult animal. In the last condition its body was enclosed in tri-lobed joints, which served as a defence, and at the same time were flexible enough to be adjusted to all the motions of their possessor. In fact, they served all the purposes of an ancient coat of mail. These various species of Trilobites literally swarmed in every sea of the Silurian period. There were species alike peculiar to deep water and to shallow, and the rocks formed under these different conditions (as I have above related) indicate which these species were. Well do I remember them crawling over the oozy sea-bottom, gorging the mud, as I am told earthworms now do, for the sake of the animalculous matter dispersed through it. Not long ago, some of these fossils were found which were supposed to have the legs attached to the under side. As a rule, however, the Trilobites are usually met with without these useful appendages, and no small discussion has arisen as to whether they had them or not a discussion which is now set at rest. When any danger approached, they coiled themselves up like modern woodlice, and, in this state, you may not unfrequently find them fossilized. When the adult animal moulted, he did so at the junction of the head and carapace ; and this accounts for the myriads of detached heads and tails found in every piece of Silurian limestone or shale. The Trilobite had compound eyes, arranged sessile, on half-round prominences, on which they were set like so many mounted jewels. Some species had not less than four hundred of these distinct eye-facets. Thus we find the structure of this little creature completely setting all those wild theories at defiance in which some people have indulged. Their eyes indicate a similar constitution of the atmosphere then to what it is now, for the passage and refraction of the rays of light. And this fact is supplemented by the sun-cracks, rain-drops, &c., which pit the sandstones, telling of meteorological action identical in its operation with the present. Indeed, all the facts go to prove that even at this distant epoch of the world's history, the light of the sun and the atmosphere of the earth were exactly like what they are at the present time.

During the period of the " Middle Silurian" there was a great change in physical geography. How long a time had elapsed since the Lower Silurian strata had been formed, with their enclosed great sheets of volcanic lava and ash, may he guessed at from the fact that the May Hill conglomerates are composed of the waste fragments of the former ; they had therefore been solidified into such rock as you now see them, and been uplifted from the sea-bottom into coast sections, and it was from their wear-and-tear, when in the latter condition, that the May Hill conglomerates were formed. Thus does the very structure of many of these deposits indicate the immense amount of time which elapsed during their elaboration. It was during the deposition of the " Upper Silurian" beds, however, that life was most prolific—was most varied. The sea was aglow with huge coral reefs, around which swarmed sea-lilies, star-fish, mollusca of innumerable species, nautili, orthocerata (of whimsical and various shapes), and trilobites. The scene was most busy and most animated ; the compound corals shone in various colours, and the adjacent sea-bottom was literally a submarine forest of crinoids, or sea-lilies. How abundant these lovely creatures were you may guess from the fact that you can scarcely pick up a fragment of Upper Silurian limestone without perceiving some of their detached ossicles, or jointed plates. In and out of these waving forests, with the arms of the animals representing branches, the innumerable species of trilobites swam, and crawled, and climbed. Every now and then some brightly-coloured *pecten* flitted past like a butterfly. Univalves (*Murchisonia* and *Euomphalus*) of delicate ornation and colour, slowly dragged their pretty shells about ; the Cystideans, with their dwarfed stalks, but highly-ornamented and sculptured heads, dotted the sea-bottom. Over all, the occasional long arms of star-fish wound and unwound ; delicately beautiful nautili, of various species, sometimes crawled, sometimes filled their air-tubes, and mounted to the surface of the water. The whole of Wenlock Edge, in Shropshire, is nothing less than an ancient Silurian coral reef, around which, millions of years ago, all the vital circumstances I have been attempting to describe

took place ! Of all these beautiful coral forms none were so lovely as the " Chain-coral" (*Halysites catenulatus*). Well does it deserve its name, for even now it appears like some watch-chain of exquisite workmanship interfolded in the solid rock ! The largest of these corals was the *Favosites polymorpha*. Amidst all should not be forgotten the nests, groups, or even banks of *Terebratula*, *Atrypa*, *Rhynchonella*, *Spirifera*, *Producta*, *Strophomena*, and *Pentamerus ;* all of them belonging to the lowest class of Mollusca, then in luxuriant abundance, but now waning into extinction. Towards the close of the Upper Silurian period, V*ertebrata*, in the form of fishes, made their appearance : at first they were few in number and small in size : but ere long they multiplied amazingly. They had their old feeding and breeding grounds, and along this part of the old sea-bottom their remains were of course most thickly accumulated. Such is the explanation of the Ludlow bone-bed to which I have already alluded. I am told that off the western coast of Ireland, near Rockall, such a bone-bed is now actually in course of formation ; so that if it becomes covered over by succeeding deposits, it may one day present a similar appearance. Of the land plants of the Silurian period I cannot say much ; but that the dry land was more or less clad with green I have not the slightest doubt. What makes me feel so confident about this is that the small spores of club-mosses are to be found fossilized in the " bone-bed" I have mentioned. You can only see them with the microscope, but there is no doubt as to what they really are. These spores must have been carried by the land-breezes seawards, and strewn over the surface of the ocean until they sank, and were buried in the deposits accumulating along the bottom, where the bony-scaled and shagreen-skinned little fishes were living, breeding, and dying.

My story is now finished, for the formation of cracks and fissures in our solid rocks belongs to a later time. Of the minerals and metals which were segregated along the walls of these fissures until the latter became " metal lodes," I cannot say ; but thus much—that, apart from the numerous fossils contained in us, our rocks will always be esteemed interesting to man, seeing that it is in them that the over-valued metal gold is most abundant.

The Story of A Piece of Sandstone.

" You may trace him oft
By scars which his activity has left
Besides our roads and path-ways (though, thank heaven,
This covert nook reports not of his hand),
He who with pocket-hammer smites the edge
Of every luckless rock or stone that stands
Before his sight by weather stains disguised,
Or crusted o'er with vegetation thin,
Nature's first growth, detaching by the stroke .
A chip or splinter to resolve his doubts;
And with that ready answer satisfied,
Doth to the substance give some barbarous name,
Then hurries on ; or from the fragment, picks
His specimen."

WORDSWORTH'S *Excursion.*

LIKE my mineralogical acquaintance, the piece of limestone, generally I am about to do duty for a group of individuals common to every geological formation. But each of us has a separate story to tell, and I shall find it quite sufficient to bring all the circumstances of the epoch in which I lived sufficiently clear to my own recollection. It is said that a number of people who live in the present period (so far removed in time from mine) profess to be able to interrogate a piece of limestone or sandstone, by what they term *Psychometry*, and to get its story in some easier way than by the ordinary cross-questioning of science ! All I can say is,

I wish the events of my own life were so permeated in my substance. If this theory be true, the modern science of geology will have to give up induction, and fling itself into the arms of the spirit-rappers !

Every one of my listeners knows what a piece of sandstone is like. There is no need for me to describe my appearance, therefore, as novelists do their heroes. But how many thus familiar are aware that in ninety-nine cases out of a hundred every such piece of sandstone was originally formed along the floor of ancient oceans ? Those ocean bottoms are now represented by dry land surfaces, where the vegetation luxuriates on the mineral substances accumulated under such widely different circumstances. Even where no marine organic remains are present, as fossils, to prove the marine origin of the sandstones, that origin is none the less certain. I cannot speak with certainty as to the nature and extent of the dry lands and continents of the epoch in which I was born. Suffice it to say, they must have been great, for the rivers which watered them were large, and brought great quantities of mud and sand down to the sea. The ocean currents and tides also wore away the coast-line, and added to the quantity of loose sand and mud which accumulated under the waves in consequence. Thus it was that I was born.

My earliest remembrances are of my lying loose and unconsolidated on the ocean-floor, and of constant additions being made to the sheet of which I formed part. It was whilst I was lying in this state, as so much ordinary sand, that I received my impressions of what was going on around me. These consisted of a familiarity with the commoner animals which lived in the sea, or with occasional plants and vegetables which had been carried there by rivers, until they sank to rest in my bosom when they had arrived at a water-logged condition. Of these I will speak presently. Meantime let me make a few remarks as to the changes which transposed me from loose marine sand into hard sandstone ; and in doing so, it will be evident that the same explanations will answer for the similar alteration of sandstone rocks, both of earlier and later geological periods.

The sand or mud brought down and laid on the sea-floor in the manner I have mentioned was not of an absolutely pure character as regards its mineral composition,—that is to say, it was not all silica, or alumina, as the case might be. In most instances the material was mixed with more or less of iron rust, or of lime, and silica. The two latter acted as cementing pastes to those sandstone rocks which are now of a lightish colour ; whilst the iron was the compacting agent with such dark red rocks as that of which I form part. Indeed, in most cases, even when the sandstone is of a light yellow, a small percentage of iron has gone a great way towards binding the loose grains of sand together, and thus producing a hard rock. When this chemical agent has been equally dispersed through the sandy mass, you have the thick-bedded sandstone, or " free stone." When it was intermittent in its action, or unduly mixed up, or occasionally alternated with something else, then the sandstone becomes " flag-stones" of greater or less thickness.

Sometimes you will see a mass of red sandstone more or less mottled. This has been caused, in most instances, by patches of vegetable matter—old world *fucoids* or something of that sort,—which decomposed, and whose chemical changes combined with the iron, and locally prevented its colouring effect.

Of course it will be evident that our hardness or softness greatly depends on the percentage of cementing material, or to the different circumstances under which we were formed. I. have no doubt that, when the chemical changes above mentioned were going on through an immense thickness of accumulated sand, the hardening process was greatly assisted by the pressure of the overlying volume of sea-water.

The epoch to which I belong is sometimes called the " Old Red Sandstone," and, occasionally, the " Devonian." The former term is given to our formation to distinguish us

from the " New Red Sandstone," overlying the coal-measures ; whilst the latter name is of local origin, and indicates that the system is largely developed in the lovely county of Devon. Indeed, that sunny land owes no little of its physical attractions to the various mineralogical structure of the rocks of our formation. Perhaps I can boast of the fact that there are few other formations which have such a world-wide extent as that to which I belong. In the United States it stretches over an area nearly as large as Europe, there being one continuous coral reef included in it which covers an area of nearly half a million of square miles. In Canada there is also a great extension of this formation ; whilst in South Africa its area is greater still. In Russia one sub-division is much greater than the whole of England, and there is a large extension of beds of similar age in Asia Minor, as well as in Australia.

The original name of " Old Red Sandstone,"—given to the formation of which I am a humble part, was conferred upon the thick beds found developed in Herefordshire, Worcestershire, Shropshire, and South Wales, as well as others supposed to be of similar age in Scotland. In the former localities they attain their greatest thickness, which is between eight and ten thousand feet. There geologists have divided the series into four divisions, of which the lowest may be said to blend with the underlying Silurian formation, and the uppermost with the succeeding Carboniferous. In Scotland the beds are not so thick, their greatest vertical accumulation amounting to about four thousand feet. It would seem, therefore, as if the material which formed these rocks came from the south-west, thinning out in a north-easterly direction. In Devonshire, as well as in Ireland, there are two series of strata included in the same formation, which seem to have had quite a different origin. The former indicate a sea in which coral reefs abounded, and the latter tells us plainly of a large continent which existed towards the end of this epoch, on which there were freshwater lakes as extensive as those of North America. Perhaps it was the same continent whose rivers contributed no little of the sand and mud which, when strewn on the sea-bottom, formed the sandstones of which I am part. I am told, however, that there are some geologists who imagine that all these red rocks were of fresh-water, and not marine, origin ; but I think that their immense area will convince you that this could not be the case.

How shall I tell of the strange sights which I beheld when quietly lying on the ocean-floor ! The sea-water had the same specific gravity it has now, and the constitution of the atmosphere was similarly formed. It is an error to suppose, as some have done, that there was mixed a large percentage of carbonic acid in the air before the Carboniferous epoch, and that this was absorbed by the plants, and the atmosphere cleared and rendered fit for animal life at the same time. The theory is ingenious, but there is not the slightest ground for believing it has any foundation in truth. Occasionally the sea-water became turbid and red, owing to larger quantities than usual of the refuse of igneous and metamorphic rocks being carried down by the rivers. As is well known, these contain large quantities of iron, which are easily decomposed, and enter into new combinations as oxides ; whence my colour and also my cementing agent. The sea-bottom was covered with groves of *fuci*, or sea-weeds, in which a large crustacean, bearing some resemblance in its huge claws to the modern lobster, lived and left its spawn. The latter is actually found fossilized in our sandstones, and bears some resemblance to a flattened blackberry. Among geologists, I am told, it goes by the name of *Parkia*, whilst the huge lobster which left it, and which was at least six or seven feet long, rejoices in the name of *Pterygotus*. Several species of this common form are met with in Scotland, as well as in England. Another large crustacean, which appeared during later Silurian times, and was nearly related to the *Pterygotus*, now goes by the name of *Eurypterus*, on account of the breadth of its swimming feet.

But by far the commonest creatures which enjoyed life in the sea of my birth were the fishes. Indeed, my epoch has been justly called " the age of fish." In many places they swarmed in shoals. Most of them belonged to an order of which there are very few now living, termed the *Ganoid*, on account of their being covered with a series of oval or

rhomboidal bony plates, instead of scales. These bony plates had an exterior varnish ; whence their name. At present, I am told, there are several species living in the rivers of North Africa, and others enjoying life in the lakes and rivers of North America. But out of nine thousand species of fish known to naturalists the *Ganoid* species only number about twenty-nine. Indeed, the wide geographical areas where the two outliers of this once numerous and world-wide family of fishes are now lingering, indicate their antiquity, and suggest how many geological phenomena have taken place to bring about their present geographical isolation. By many it is supposed that the whole of this family would now have been extinct, had it not been for their withdrawing from the keen battle of life that subsequently went on in the seas by the introduction of other species, and so confined themselves to fresh-water condition. Few of these peculiar species have a bony skeleton properly hardened, as is the case with ordinary thin-scaled fishes. No doubt the strong, bony integument did duty instead. Indeed, among the fish which lived during my lifetime, scarcely any possessed a solid skeleton. The largest of these strange-looking fish is now called *Asterolepis* from the star-like markings on each of the scales. It reached the entire length of between twenty and thirty feet. Other common forms were the *Holoptychius*, noted for its large oval scales being peculiarly wrinkled ; the *Pterichthys*, or " winged fish," so called on account of its two pectoral fins, which are very large and resemble paddles, being placed near the head, where they look like wing appendages. The plates which covered this fish were very large, and ornamented by a series of granules. The former of these two species lived in what is now America, Russia, and England, and Scotland.

Then came the *Cephalaspis*, or " buckler-headed" fish, so called because its queer-shaped head was encased in a shiny bony buckler, in form riot unlike a cheesemonger's knife. Its trilobed body was covered with lozenge-shaped bony plates. The *Osteolepis*, or " bony-plated" fish, was the most abundant ; its name being derived from the minute rhomboidal plates which covered its body, and protected it, like the links of an ancient coat-of-mail. Besides the fishes of this class, which, singularly enough, were further distinguished by their having the tail unequally lobed—and not regularly cleft as in the common herring and other scaled fishes—there were associated with them others, having an affinity with species of the Shark family. These are called *placoid* fishes, on account of the skin being a kind of shagreen, dotted with minute plates or points of hard bony matter. They also have a cartilaginous skeleton, as, for instance, the common skate, sturgeon, &c. Well do I remember the above fish, ranging in size from the *Asterolepis* to the little *Onchus* and *Osteolepis*, of only a few inches in length ! The quick, active movements of the latter fishes, as they roamed in and out of the thickets of seaweeds, caused the light to flash from their enamelled scales, and sometimes only too surely pointed out their playgrounds to their cestraciont enemies. They had their feeding and their spawning-grounds, and each of these places is now represented by the greater number of fish found fossilized in the flagstones, as in the Caithness flags, and the yellow sandstones of Dura Den.

Sometimes, also, great numbers were killed by unusual quantities of mud being poured into the water and choking them, as a turbid river will, at the present time, suffocate the smaller of its tribes. How suddenly these died is indicated by the fact that thousands of fossil specimens are to be seen with their fins erect, like those of the *perch* when he is " struck by the angler." Others are contorted and bent, as if in pain ; their last dying struggles having thus been faithfully handed down by the stony records in which they were imbedded.

Some few of the fossil fish of this period had *reptilian* characters in their teeth, &c., indicating and linking on, as it were, the next great family which should rule creation. Wherever the Old Red Sandstone has been met with, some, if not all, of these peculiar ganoid fishes have been found fossilized. Therefore they are good indications of the geological age of any such formation.

I will not trouble my listeners with the dry, technical details of how the strata succeed each other in my parent formation. I want, if possible briefly but vigorously to sketch the life-characteristics of that distant epoch.

I have thus far devoted myself to the fossil fishes because of their abundance, and also of their very striking peculiarities. I now come to other creatures, perhaps not less abundant, but not so attractive. I must premise, however, that such marine creatures as corals, mollusca, and trilobites were not very abundant over the area where I first saw the light. They delighted in clearer water, and so are to be found over the area where that existed. Indeed, generally speaking, those parts of the sea-bottom where most of the red muddy matter was poured in were shunned by all forms of life, not excluding the hardier fishes. Hence it is you rarely find, in the very red sandstones any organic remains or fossils beyond a few vegetable impressions. Of course there were various parts of the same sea thus distinguished by different physical circumstances, and life was developed, or located accordingly. Let me, therefore, give you some slight account of the area where " blue water" was most in force, and where, in consequence, there were the most numerous assemblages of Crustacea, shell-fish, and corals.

The localities in Great Britain where these peculiar fossils are found in strata of the age I am describing, lie chiefly in South Devonshire, as well as along the North Devon coast. At the latter place you may see beds of sandstone, red and yellow, alternating with slates, limestone bands, &c., the last-mentioned being especially full of organic remains. The total number of species of fossils of all kinds which have been found in Devon alone is three hundred and eighty-three.

The highest of the series go by the name of the " Pilton Group," and these are perhaps of the same geological age as the Devonian strata in Ireland. Among the fossil shells which lived during this epoch, and which occur at the above-mentioned places in the fossil state, the most numerous were those belonging to the *Brachiopoda*. Indeed, these shells far outnumbered the ordinary and more highly-organised conchifera, whereas at the present time the latter are by far in the majority.

Among the commonest of the shells I remember were several species of *Spirifer*, *Stringocephalus*, &c., and also of *Clymenia*, *Megalodon*, and others. The last was a lamellibranchiate mollusc, allied to the oyster and mussel of the present day. Among the corals there abounded in Devonshire the *Favosites polymorpha*, or " many-shaped" coral, as well as H*eliolites*, or " sun-coral," *Strombodes*, &c. The latter my readers will readily recognise when I tell them it is the common pink or red variety usually bought at Torquay, and which, when polished in the mass for mantel-pieces, has such an attractive appearance. All of them are portions of reef-building corals, and well do I remember the animated appearance of the clear water when the " reefs" nourished in their bright colours, and trilobites, fish, and crustaceans swarmed around the busy pile. The *Trilobites* found in the Devonian limestones are of a peculiar type, equally distinct from those of the preceding Silurian period, or of the succeeding Carboniferous. Among the commonest of the genera were *Brontes*, noted for its fan-like tail, and *Homalonotus*, equally distinguished by the double row of small spines running down the central lobe, and which give to it a more " trilobed" appearance than any other species in the whole family. But, clear though the sea-water generally was in which these Devonian beds were formed, every now and then shifting currents brought fine mud and other sediments. These were thrown down on the ocean-floor, where they alternated with the bands of limestone.

Eventually, the sea again maintained its purity for a long period, during which the corals and other clear-water-loving animals resumed their avocations, and left behind them traces of their work.

I have said that where Ireland now stands, was part of a great continent, or some other extension of dry land, towards the close of the age in which I was born. Of this I cannot speak with certainty ; but the evidence is strongly in favour of the idea. In the country of Kilkenny are a series of fine-grained greenish sandstones, regularly bedded ; they are full of evidences of fresh-water deposition. Nowhere, in Europe at least, will you met with such well-preserved land-plants ; all of which prove, by the perfect manner in which they have been preserved, that they could not have been drifted from a distance, or been in the water long. Among the most attractive of these remains are those of a tree-fern, formerly called *Cyclopteris*, or "Round-leaved Fern," but now named *Palæopteris Hibernicus*, or the " Primitive Irish Fern." Nothing could be more exquisite than this beautiful fern, even in a fossil state, and you may therefore guess how attractive were its groves when it was the monarch of the primeval forests, and its graceful fronds bent over the clear waters of a lake which equalled in picturesqueness those of the Emerald Island of these times.

This fern is not unlike, in general appearance, the modern " Royal Fern" (*Osmunda regalis*), with the exception that it has no mid-rib its veins ramifying from the base towards the exterior of the leaf. Associated with this tree-fern were great and small club-mosses, which trailed over the ground, and formed a rich green carpet of various tints. Among the commoner of these extinct club-mosses were *Sagenaria* (of which the seed-vessels and catkins are well preserved) ; *Psilophyton*, a simpler club-moss, and the larger and more tree-like *Lepidodendron*, which afterwards became so abundant during the Carboniferous epoch.

Besides these we have evidences of other kinds of vegetation, and there is no doubt that the higher grounds were more or less covered with more highly-developed and organized species. What is further corroborative of the fresh-water origin of the Irish sandstones is the immense number of bivalve shells, exactly resembling the large fresh-water mussels (*Anodon*) which abound in modern English rivers. Both in appearance and structure these fossil shells are evidently closely allied, and therefore they are called *Anodonta*. They abound by thousands in some parts of the sandstones, associated with plant-remains, and with those of crustaceans which seem allied to the modern crayfish. So long did these large Irish lakes exist, that mud was strewn along their bottoms which ultimately formed rock several hundred feet in thickness. I am told that similar deposits of fine mud and shell marl are now going on along the floors of the forest-fringed lakes of North America. Change the character of the vegetation there, and you have no indistinct restoration of the Irish Devonian lakes. Many of the fish would do ; for the " bony pike," a ganoid fish, still lives there, associated with colonies of " swan mussels" (*Anodon*) clustering on the bottom.

So much for the brief outlines of my story. Much more could be said upon this remarkable epoch ; but if I have given anything like an idea of my origin and of the character of the life-forms with which I was brought into contact, my business is done, and I accordingly retire for another geological speaker.

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Our planet's earliest existence seems to have been that of a cosmical mass a sort of world-fog or vapour something like those revealed by the telescope as being still in existence. Some of the best astronomers have shown that the probable origin of the entire Solar system has been a condensation of this cosmical vapour into planets, satellites, and planetary rings. Whether this was the case or not, it is certain that there is much in the shape and physical constitution of the planets to lend support to the idea. But, with the oblate shape of our globe, and its probable evolution from a cosmical mass, the geologist has little or nothing to do. But he knows, from the fact of igneous rocks having repeatedly been injected into the stratified rocks, so as to bind them together, as mortar does the bricks of a wall, that the interior of the globe still contains molten matter.

The first time the geologist can lay his hand on a formation distinct in its character from the primitive igneous rocks, it is when he comes to the Laurentian system. They are thirty thousand feet in thickness, and so contorted and changed by the pressure, heat, and mechanical forces to which they have been subjected since the infancy of the world, that all original characters have been obliterated. But, by the aid of the microscope, the explorer is yet able to discern that the ancient sea along whose floors these mica-schists, gneisses, and quartzites were deposited as muds and sands was not a lifeless area, but was tenanted by lowly creatures after their kind. The only solitary known fossil from the altered limestones of the Laurentian formation—the *Eozoon*—is sufficient to prove this. And from the occurrence of this lowly-organized creature up to the present, we never afterwards lose sight of the graduated life-scheme recorded in the rocks ! There is many a difficult chapter to spell out, many a leaf missing, but there is still sufficient left to interpret the stony scroll.

Above the Laurentian system lies the Cambrian. But we should remember that this classification of the rocks into formations and systems is, at the best, but a harsh and forced one a remnant of the time, not long ago, when men believed there were distinct creations and destructions of separate faunas and floras. Geological and, in fact, all natural history classification is but an arbitrary arrangement to enable the human mind, in its faintness, to grasp and arrange the multitudinous facts presented to it. In reality there is no separation of geological systems, but more or less of a graduation of one into another. The world's biography is like a man's, not like a butterfly's, consisting of metamorphosed states, each unlike the other, and definitely separated from it. In the Cambrian formation, we find that life, which had begun, as it were, from a point, was radiating like the rays of light from a focus. Here we find the lowest order of shell-fish (*brachiopods*), worms, and, towards the later period, Crustacea.

But it is in the Silurian system that we find the stream of life broadening out. The seas are full of coral-reefs, bivalve and univalve shells, huge Crustacea, tolerably highly-endowed Trilobites, &c. At the close of the formation, we came on placoid fishes, the first *vertebral* types. Thus we find a *lateral* development of species, in size, and a *vertical* one in organization. Then comes the Devonian, or Old Red Sandstone epoch, whose seas abounded in strangely-clad and gigantic ganoid fishes, and whose deeper waters were busy with the manifold complexities of marine life. The dry land was scantily covered with a thin vegetation of a cryptogamous type, or of the lowliest of the exogens. Great fresh-water lakes existed, set in beautiful frameworks of tree-fern and huge club-moss. But it is when the Carboniferous era commences that we find abundant evidence of a dense flora, although one of a very lowly kind. Every foot of dry land, where the circumstances were favourable, seems to have been densely covered with forests, the trees of which now find their nearest allies in our " Horse-Tails" and club-mosses. Enormous *Sigillaria*, *Lepidodendra*, and tree-ferns constituted this vegetation, whilst there was no lack of species of Conifera. In the Carboniferous limestone period, which immediately preceded that of the coal measures, we have ample evidence of seas in which life was very abundant, where floors were covered with thick submarine forests of sea-lilies, and which had numerous colonies of brachiopodous shells. Cephalopods, such as *Orthoceras*, *Nautilus*, and *Goniatites*, abounded, and thus the huge thickness of limestone rocks grew out of their accumulated remains. The fishes were bony-plated, and, in the structure of their teeth, many of them showed decided reptilian affinities. It was in the waters of the Carboniferous seas that the first reptiles appeared, as the *Archægosaurus*—a creature belonging to the lowest order of reptiles, the amphibia. It exhibits decided affinities to the fish, as the ancient fish do to the reptiles.

In the Permian epoch, geologically brief though it was, the physical geography seems to have been varied. Here we have evidence of a cold climate, and of glacial conditions, during which the " breccias" were formed. Reptiles of a higher class abounded, and these are now known as *Thecodonts*. With the close of the Permian, we have the termination of the Primary, or Palæozoic division of geological time.

The Triassic epoch, or that of the New Red Sandstone, offers to us fresh scenes and new creature forms. Huge frog-like reptiles abounded, and left their numerous foot-prints on the soft muds. In the deeper seas, new species of sea-lilies grew, and new forms of cephalopods, such as *Ammonites* and *Belemnites*, existed side by side with the old-world forms, that were now rapidly dying out. Thus the Triassic limestones of Germany are as crowded with organic remains as the mountain limestone of Derbyshire. Elsewhere, the dry land was covered with saline lakes, or " Dead Seas," along whose floors Rock-salt was deposited. In America, the first *birds* appeared, whilst at the close of the Triassic era in Europe we have distinct and sure proof of the first introduced mammals. The latter belong to the group which all naturalists have by common consent placed at the bottom of the sub-kingdom mammalia. Thus it will be seen that the order in which the new groups of animals appeared on the stage of creation, is also that which we have ourselves arranged, more or less, as that of true succession.

With the Lias, we have the commencement of that " Age of Reptiles" which well deserves the name. New forms of cephalopods appeared, the *Ammonites* literally swarming in the seas, and actually forming limestones by their accumulated remains. New and complete species of sea-lilies grew on the ancient ocean-floors—new plants, cycads and zamias, as well as complex-veined ferns, on the dry land. But the chief animal forms which strike the eye are the reptiles—modified then to every condition of life, as we find the mammalia are now. As *Ichthyosauri* and *Plesiosauri* they were the tyrants of the deep ; and as *Pterodactyls* they winged the air like bats, their size being often bigger than that of any existing bird. During the succeeding Oolitic period, huge reptiles lived on land, such as the *Megalosaurus*, *Hylæosaurus*, and *Iguanodon*. Some of the reptiles walked on two legs, like the modern kangaroo, and were decidedly allied to birds. The first known European bird now put in an appearance, its feathers and bones having been found in the Solenhofen slates. It had a long vertebrated tail like that of a lizard, feathered down to its tip. In other respects also it possessed reptilian affinities. Mammalia abounded, but still as marsupials, although there had been a division into herbivorous and carnivorous species. We have evidence of great fresh-water lakes, along whose floors thick beds of limestone were formed by the slow accumulation of *Paludina* and other fresh-water shells. A. great river watered a great continent, and at its mouth was formed a Delta, since known as the Wealden formation. Out in the blue sea, coral reefs fringed the rocky coasts ; bony-plated fishes and sharks were in plenty, some of the former living on the mollusca.

Then comes that period of great depression when the chalk strata were formed along the floor of a very deep sea, as its organisms plainly prove. For this white chalk is chiefly made up of shells so minute that the naked eye cannot perceive them. Many of the same types of marine creatures still lived, reptiles, brachiopods, and cephalopods. Echinoderms were more abundant than ever, and their remains are to be found in every chalk quarry. A peculiar reptile, the *Mososaurus*, lived in the deep sea, and was a most formidable animal. The sea-bed produced dense crops of sponges, great and small, some of them of as ornate a character as the recent " Venus' Flower-basket." On the dry land, towards the close of the period, there appear for the first known time trees of a higher order, such as the Oak, Walnut, and Elm. Thus came to a close the Secondary or Mesozoic division of geological time, during which we have seen animal and vegetable forms attaining higher and complexer organizations. The last, or Tertiary epoch, commences with the Eocene beds, in which warm-blooded animals appear so common, that the Tertiary has been not unfitly called " the Age of Mammals." Many of these mammals united characters which since then have been distributed among half-a-dozen later animals. In fact, nearly all the Eocene and Miocene mammals are veritable " Missing Links !" We have, in the former period, evidence of at least a sub-tropical climate in Britain : palm-trees, tree-ferns, &c., grew abundantly. The seas had what we now regard as sub-tropical shells, *Typhis*, *Volutes*, *Cones*, &c., living in them, as well as turtles, sharks, sword-fish, &c. In the rivers, gavials and crocodiles wallowed. Towards the close of the Eocene, *monkeys* made their appearance in English woods ; whilst

in the Miocene period, they swarmed in several species all over Europe, one of them, singularly enough, being more anthropoid, or “ man-like,” than any now in existence. Extensive forests of warm temperate plants grew all over the northern hemisphere during the Miocene age ; and there does not seem to have then been any ice-cap at the North Pole, for these virgin forests grew in Iceland, Greenland, and Spitzbergen. Elephants and mastodon, camels and giraffes, deer and oxen, now made their appearance. Great fresh-water lakes existed in Switzerland, along whose bottoms the decaying vegetation accumulated to form Lignite beds. In central France, Scotland, and Ireland, volcanoes were very active, as the lava sheets plainly prove.

In studying the Miocene plants, shells, &c., we come across the same genera as are still in existence, so that the naturalist cannot turn away from the impression that many of our modern species are lineal descendants. In the " crags " of Norfolk and Suffolk, this impression rises to a certainty, for in them we actually do meet with hundreds of species of shells of exactly the same kind as those still in existence. These “ crag” beds belong to the succeeding Pliocene period, and they tell us very plainly of a refrigeration, or toning down, of the climature. This indication is fulfilled when we study the beds of the Northern Drift those accumulations of sand, gravel, and clay which occupy the area of the northern hemisphere. These were all formed under glacial conditions, and Europe lay for centuries beneath a thick swathing of land-ice. Arctic plants and Arctic mollusca lived in British latitudes. Our higher mountains sent forth streams of glaciers, which scratched and pounded the solid rocks over which they moved. In British seas icebergs were continually stranding and floating, dropping their burdens of sand and gravel, as well as the huge masses of rock which had been frozen into them. As boulders we frequently meet with these erratics, which had thus been carried miles from their native or parent bed.

It was after the elevation of the glacial sea-bed into dry land, when the climate had toned down from its arctic vigour, although still much colder than it is now, that MAN first appeared on the scene. His rude flint implements have been found abundantly in the valley gravels of existing rivers, formed when those rivers had a greater volume of water than they have now. From that distant time to this, we never lose sight of him and his works, and there is exhibited in his history a similar development, or elevation, from a lower to a higher stage, to that which we have seen marking the lower animal and vegetable kingdoms in their appearance on the platform of existence. But it does not follow that because we can plainly trace the mode in which Deity has chosen to operate, that therefore He has been superseded by His own laws. Bather, it brings Him awfully near, for in the constant regulating and leading upwards of the organic world we never escape His presence !

[1] The larva or young of the King Crab very much resembles some of the ancient Trilobites.

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