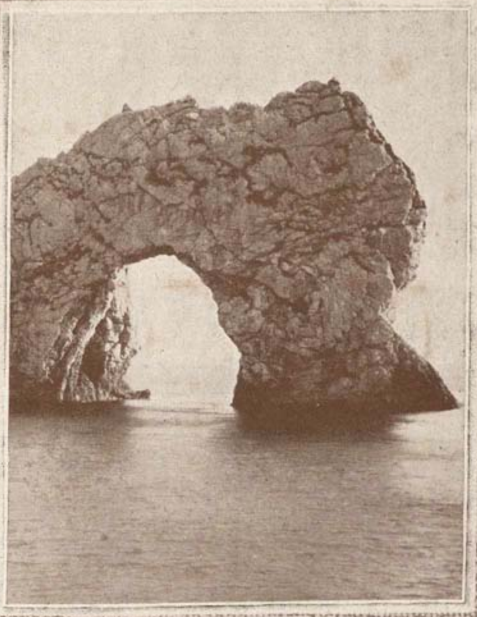
THE WORLD IN THE PAST

WHAT IT WAS LIKE & WHAT IT CONTAINED

BY
B. WEBSTER SMITH



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THE WAYSIDE
AND WOODLAND
SERIES

THE WORLD IN THE PAST

Here is given a popular account, in simple, non-technical language of the wonders recorded in Nature's Great Stone Book of the Earth. Every cliff, field, quarry or river has a tale to tell. We wander amongst the Coral Islands, Mountains and Volcano Craters. We read of the Birth of the Earth and the Dawn of Life; the Successsion of Ages, each characterised by its own peculiar form of life. Every student of nature will be thrilled by this most interesting story of the world when it was young.

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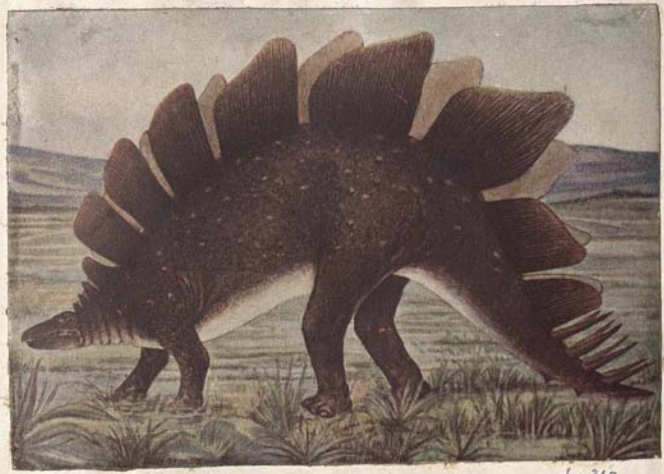

p. 210.

W S

Pl. I. *Frontispiece.*

Skull of Tyrannosaurus.

The largest flesh-eating reptile known (p. 207). This skull is over 4 ft. long, and proportionally broad.

THE WORLD IN THE PAST

A POPULAR ACCOUNT OF WHAT IT WAS LIKE AND WHAT IT CONTAINED

BY

B. WEBSTER SMITH

MEMBER OF THE GEOLOGISTS' ASSOCIATION; MEMBER OF THE MARINE BIOLOGICAL ASSOCIATION OF GREAT BRITAIN

SECOND EDITION
REVISED AND ENLARGED

WITH 266 ILLUSTRATIONS
73 OF WHICH ARE PREPARED IN COLOUR
BY W. J. STOKOE

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PREFACE

In the preparation of a book of this nature, many acknowledgments of assistance, direct and indirect, must be made.

Primarily, I am indebted to all those whose labours during the past hundred years are herein summarised: the names of Lyell, Strahan, Geikie, Walcott, de Lapparent, Hayden, and a dozen others rise at once to one's mind. In this connection, I wish to make it clear that where matters of opinion are referred to in this volume, the opinions expressed are my own, unless the context shows that this is not the case.

Secondarily, and more directly, I am indebted to many people for the loan of beautiful illustrations, and in particular, to the following:—

Plates 1, 57, 60, 63, 71, 73, 100, 105: The Director, The British Museum, Natural History.

Plates 16, 36, 69, 94: The Director, H.M. Geological Survey of Great Britain.

Plates 77, 78, 81, 82: Dr. E. M. Kindle, The Canadian Geological Survey.

Plates 80, 86, 87, 98, 103: The Director, United States National Museum.

Plates 2, 67, 91, 108: Schweizerische Bundesbahnen.

Plates 3, 6, 33, 76, 104: Canadian National Rlys.

Plates 5, 25, 44, 52, 53: Atchison, Topeka and Santa Fe Rly.

Plate 8: Denver and Rio Grande Western Rly.

Plates 9, 17: Japanese Imperial Rlys.

Plates 12, 15, 34: South African Government Rlys., Publicity Dept.

Plates 13, 14: Mr. J. D. Mason, El Paso, Texas.

Plates 19, 107: Norwegian State Rlys.

Plates 22, 50, 92, 99: Union Pacific System.

Plate 24: Canadian Pacific Rly.

Plate 28: Photochrom Co., Ltd.

Plate 74: Great Indian Peninsular Rly.

The whole of the colour work, with the exception of the cross sections, has been ably done by Mr. W. J. Stokoe. In particular, any success which this book may have in achieving its object of popularising geology, will be due, in no small measure, to Mr. Stokoe's rendering of Plates 11, 26, 37, 47, 56, 59, 61, 62, 65, 66, 90, and 106.

The black-and-white drawings are my own, in some cases being taken from original specimens, but in the majority of instances slightly modified (usually simplified) from published drawings in the text-books. In particular, I have reduced the coloured cross sections to mere outlines so as to make them readily intelligible to any reader.

CONTENTS

INTRODUCTION

TO SECOND EDITION

THE favourable reception which has been accorded to this little book, both by the critics and by the public, is a gratifying proof of the present-day interest in popular science. In this connection I owe a deep debt to the publishers for the generous scale on which they have permitted the illustration of the text, always an important point in such a subject as geology.

I have taken the present opportunity of correcting a few errors of style, in addition to one or two more important errors which had crept into the original text. As a result of further study, I have also modified my views in regard to the origin of the Torridon Sandstone, which very probably was accumulated on an arid land, and not in the sea. I have also radically altered my views concerning the " massif " of Tibet. I regard this little-known land as comprising, geographically, eight latitudinal mountain systems, as advocated by Hedin ; between which the valleys (which often have no outlet) have been built up to their present levels by subaerial waste. The importance of this point is that it explains how there could have been no mountains in Tibet prior to the formation of the Himalayan chain.

For the last four years I have been engaged on an extended study of the Pleistocene, and have, accordingly, taken the opportunity to incorporate one or two of my conclusions in the chapter on the Ice Age. I have also considerably amplified the list of fossil human remains ; and have added a chapter briefly describing the principal types of flint and other stone implements, besides a new plate.

I trust that these corrections and additions will make the book interesting to a still wider circle of readers.

LONDON,
July 1930.

INTRODUCTION

THE object of this book is to give a concise account, in simple and non-technical language, of some of the wonderful things that are recorded in the Great Stone Book of the Earth. The subject is a vast one, with ramifications extending into numerous sciences; but by a rigid exclusion of scientific phraseology, it is hoped that a narrative has been compiled which will offer no difficulty whatever to general readers. For this reason, unavoidable "explanations" have been slipped into the appropriate part of the book, seemingly without order; not being a text-book, I conceive that the framework of a text-book in such a general work would be distasteful.

The world was not always as it is to-day. The relief of its surface is being altered not only from century to century, or from year to year, but from moment to moment, through the operation of streams, wind, frost, rain, the sea, and other agents. Although the activity of these natural workers may not be very apparent in the aggregate, yet in detail it is such that the most inexperienced observer may detect it. A sloping roadway, constructed of loose gravel and fine sand, can frequently be seen, after a short spell of rainy weather, to have imprinted upon it the pattern of a miniature river system:

the broad main channel, sharply incised in the road, with its tributaries of varying magnitude, down to the merest scratch upon the surface; the hills, dales and gullies; the collection of mud where the slope lessens and the water expands; the debris of leaves, twigs and pebbles, transported by the swiftly flowing waters to the edge of the nearest drain, and there dumped down: all these things are but a miniature of what goes on in vastly greater areas over infinitely longer periods of time (see Plate 8). In the one case, the connection between the cause —a few showers of rain—and the effect—carving a pattern out of a surface which is neither level nor uniform in hardness—is obvious. It is my purpose in the present volume to show that in the other case it is equally obvious, provided sufficient time be allowed for the natural agents to do their work. The data that I shall use for this purpose are all contained in the Stone Book; every cliff or railway cutting, every field, quarry, lake or watercourse, has a tale to tell, of different conditions which there prevailed in times long gone by. The pertinacious investigations of many eminent men for nearly a century have gathered the facts together; have weighed them, and assorted them; and have built them up into a consistent and harmonious whole. It is these facts which I shall weave into my tale.

The records of the Stone Book may conveniently be divided up into a number of epochs or Ages, each of which was characterised by forms of life peculiar to itself (Plates 4, 21). As we progress, we shall discover that the life of each succeeding Age was more complex and many-sided than that of its predecessors; and in the same way, the geography of the globe will more and more nearly resemble its existing outlines, as we approach modern times.

The first chapter will draw attention to the various natural agencies by which changes in the surface of the Earth are effected; and a few illustrations will be given of their actual working during historic times. This is a most fascinating branch of science; and those who may be further interested in the subject will find many eminently readable books, specially devoted to it, by such gifted authors as Lord Avebury, Sir Archibald Geikie, M. Elisée Réclus, and others.

In the second chapter, the beginning of things mundane, the bases upon which our knowledge rests, and the earliest records of the rocks, will be my theme. Not the least interesting event in these times is the dawn of Life, so far as it can be traced by fossil remains.

In the third and succeeding chapters, I shall take the reader through each of the great periods of the Earth's history, in chronological order; examining them more or less minutely, according to their relative importance and general interest. Our wanderings will take us into many strange places: coral islands, girt about with foam, where now reposes the delicate green of cultivated fields; the roots of mountains, the crags and precipices of which have long since crumbled into dust; volcanic craters that have been cold for countless years; deep and mysterious abysses of the ocean, now transformed into bold chalk downs. For the Earth is a bundle of paradoxes. Its so-called "eternal hills" can be shown to be melting away. Its rugged, snowclad peaks, the precipices of which even a goat dare not essay to scale, have often figured in the past as obscure glens, hemmed in by hills which the master-artist, Time, has since washed out. Its dales have been, time and time again, high summits. In the icy wastes of Greenland, temperate plants grew for many ages; in the stifling depths of the African and South American forests, great glaciers once stole, to levels where ice is now an unattainable luxury.

So enormous are the differences between these conditions and those under which we dwell, that the former may well appear incredible; as, indeed, they would be, were it not for the enormous body of evidence which bears, directly or indirectly, upon each separate fact, and which is indisputable. Now, in a general work such as the present one, it is not possible to present both the results and the facts upon which they are based, without inducing yawns in the reader; hence, I have given very full references to authorities, where he who doubts may find ample confirmation of what is stated here. For convenience, these references have serial numbers, and are collected together into an appendix. Where no references are given, I am solely responsible for the statements made: such statements are frequently digests of a number of disconnected circumstances, and authorities for them cannot be named without over-elaboration. But I may be permitted to remark, that the final authority in all these matters is the Earth itself. A few hours spent in examining a sea cliff, or a railway cutting, or even in watching the action of a brook as it hastens to join its master stream, are worth all the books that were ever written.

But in regard to this, as with so many other questions in life, one naturally asks, "Is the labour worth the trouble?" Come with me through the following pages, and judge for yourselves.

LONDON,
June 1925.

THE WORLD IN THE PAST

CHAPTER I.

The Tools of Nature, and how they Work.

CONCERNING MUD.

IT is extraordinary how unobservant human beings are, as a rule, of things by which they are continually surrounded, but which do not form the subject of their immediate attention. How few, for instance, of those who live in cities and daily cross bridges over muddy rivers, devote a moment's thought to the swirling brown or yellow sediment! Yet the muddiness of that water has a great and practical importance, not one whit the less because individuals are affected only indirectly by it. It renders necessary purifying plants, ere the city can have good water to drink. If the city be also a port, then that same mud is for ever silting up the estuary, affording employment to dredgers, pilots, engineers and workmen. If the city be inland, with wide flat regions between it and the sea, it is probable that these flats will be flooded during times of high water; and the mud that is deposited upon them fertilises the soil, and alters dead brown grass into rich stretches of pasture. It behoves us, therefore, to think of mud as something more than an accumulation of filth upon our clothes, for many of us live by it.

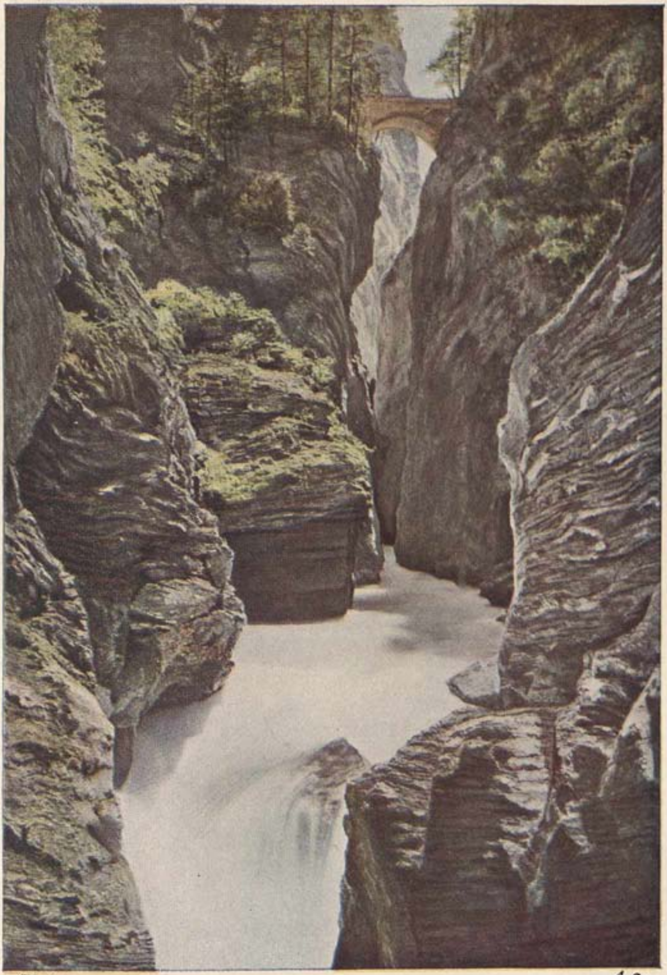
THE WORK OF A RIVER.

Mud plays an important part in the story of the Earth. Every bit of silt that goes whirling downstream towards the ocean, is a bit of the land being swept away. Consequently, every moment that it runs, the stream is cutting down its bed in some place or other, and gradually reducing the whole of its basin—slowly, it is true, but with a terrible sureness—to the level of the sea. Moreover, the mud, sand and gravel that the river transports are the real agents of destruction: water alone can effect but little, as we may see among the stones of any small cataract, which are coated with scum and weed that the water is powerless to remove. But the combined efforts of streams and the matter transported by them, effect amazing alterations in a landscape, levelling mountains to the semblance of plains, and plains into tide-swept marshes.

Many obstacles may arise during the course of these levelling operations. The river may, and frequently does, encounter quite near to its mouth a ridge of hard rock, which to cut through is a long and tedious task; and while it is gnawing away at the obstruction, its slackened current drops the mud that has been carried perhaps hundreds of miles, and builds up a land delta (if I may use the phrase) within the ridge; while its course becomes a maze of sinuous curves, like the writhing of a gigantic snake. Sooner or later, however, the gorge is sure to be cut through; when all the sediment that for many centuries may have accumulated behind the barrier will be picked up once more, and marched on to the ocean.

Rivers and their Valleys.

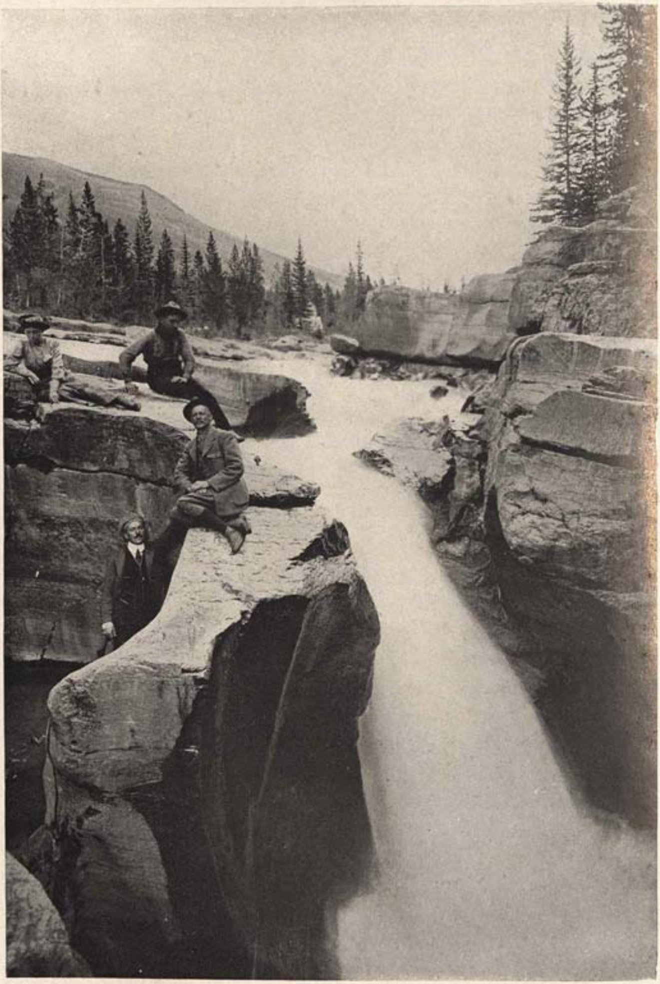
Now, if we wander through any of the charming little dales which are so characteristic of English scenery, we shall almost invariably find a stream rippling away in the bottom, its course marked by dotted lines of willow and poplar, and by the abrupt termination of fence or hedge. Comparing the size of the stream with that of the valley which contains it, we shall, as a rule, find a certain rough relationship between them; and by



Pl. 2. A 2.

Via Mala, Switzerland (p. 3).

Photo. Wehrli, Kildeberg.



Pl. 3 *A* 3.

"Pot-Holes," Maligne Gorge, Alberta (p. 4).

Caused by the falling water twirling stones round.

travelling against the current, shall observe that as the volume of water lessens, so do the valley walls close in ; until eventually, we arrive at the merest gorge or gully, with the stream reduced to a torrent that can be leaped across, a foaming stream of silver-white, dashing down from one green-crested rock to another : its source, perchance, some gurgling spring, overhung with long green moss and delicate ferns. In many another glen, too, we may perceive a similar correspondence between the size of the river and that of its valley—in so many, in fact, that the phenomenon cannot be accidental, but must be due to some definite *cause*. That cause is to be found mainly in the river itself.

This is true all over the world. Let the reader imagine himself to be some unlettered Swiss peasant, whose only knowledge of streams is the Via Mala (Plate 2). He would be vastly surprised to learn that this narrow torrent becomes, after countless windings and adventures, the majestic Rhine. Hence it is, that when (as occasionally happens) we find a mean little stream in some large valley, we feel certain that at one time the valley must have held more water, or have been scoured out by other agents. Watch a stream at work from any bridge, bank, or anywhere where the laws of property or your own daring will permit access. You will find that, in its lower or quieter reaches, the water moves only sand and silt ; whilst higher up, the rushing flood, impelled by steep gradients and impatient of control, sweeps away not only stretches of overhanging gravelly bank, but also stones so large that unaided human strength cannot budge them. In its meanders on the flat lands, too, the river is for ever impinging first on one bank and then on the other, and is slowly but surely widening the valley at the expense of its walls. By combining our observations, we shall learn that the big boulders gradually give way to smaller ones, then to medium gravel, then to fine gravel, then to sand and mud : all this is due to the attrition caused by the running water grinding the stones against each other. In this way, multitudes of fragments become so light that the swift-flowing stream can pick them up and transport them, even when its current slackens, many miles away, to meadows in its lower stretches, and thence by divers ways into the sea.

It is obvious that this incessant removal of matter from a valley must increase its depth, not only in the bed of the stream, but also in those of all its tributaries, even to the tiniest runnel. Hence, there is no difficulty in conceiving that the hills which bound the valley were at one time continuous across the river's bed: the gap through which the river flows represents the amount to which it has worn away the land. Should we have any doubt as to the capacity of the stream for such a great work, we need only examine the hills wherever the vegetation does not hide their nature; when we should find, as a rule, that the various layers or strata which compose them exist on both sides, in the same order of succession; and a drawing would enable us to connect these layers by dotted lines across the valley (Fig. 1, Plates 25, 88). Innumerable observations of this nature

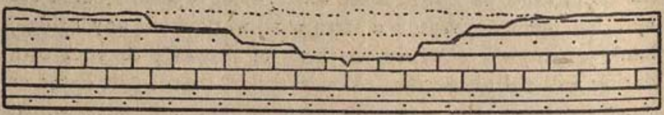


FIG. 1.—A typical plain worn into a valley by a river.

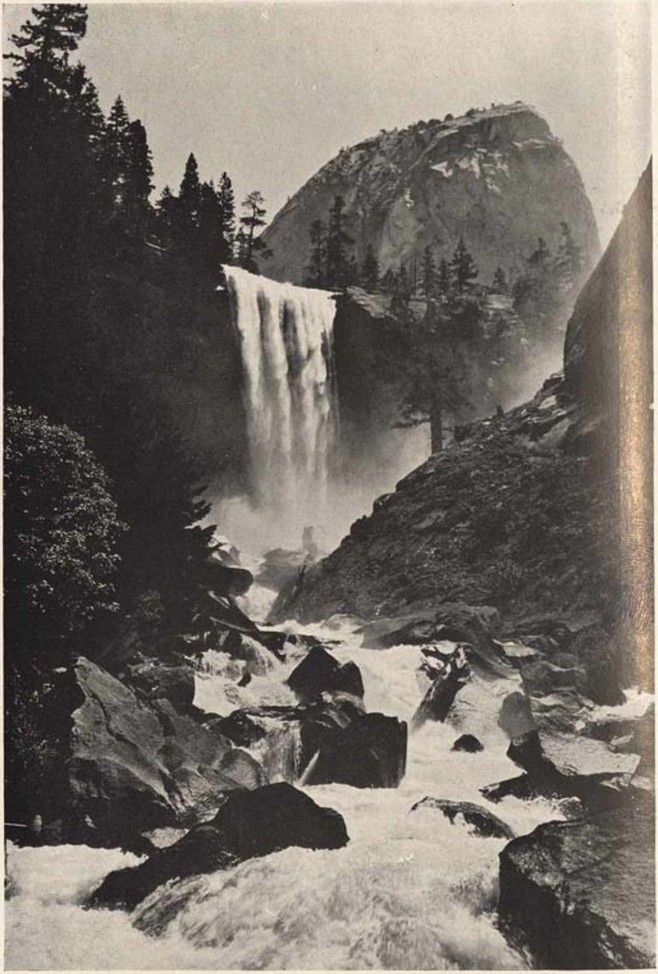
show that such hills once actually were a continuous mass, in very many valleys all over the world.

But rivers cut downwards and horizontally alone; and in any stream which is cutting away its banks we find small cliffs, and, occasionally, miniature gorges and canyons—a very different topography from the rounded hills and soft, curving slopes farther away from the channel. For the origin of these, some other agents must be invoked. The natural tools which

AGE	CHIEF FORMATIONS	TYPICAL LOCALITIES
PRE-CAMBRIAN	Lewisian Gneiss Torridon Sandstone: Longmyndian.	Scottish Highlands. I. of Lewis. Loch Torridon: Shropshire.
CAMBRIAN	Harlech Grits; Olenellus Beds. Menevian Series. Lingula & Tremadoc Beds.	N. Wales; N.W. Highlands. St. Davids. Wales.
ORDOVICIAN	Arenig Beds; Skiddaw Slates. Llandilo Beds; Bala Beds.	Pembroke; Cumberland. Carmarthen; Snowdon.
SILURIAN	Tarannon Shale; Llandovery Beds. Wenlock and Ludlow Beds; Downton Series.	S.W. Wales. Welsh Marches; S. Scotland.
DEVONIAN	Marine Limestones Old Red Sandstone.	Devon and Cornwall. Brecon. Dingle Bay. Moray Firth.
CARBONIFEROUS	Mountain Limestone. Millstone Grit. Coal Measures.	Pennine Chain; Bristol; Central Ireland. Lancashire and Cheshire. All the Coalfields.
PERMIAN	Red Marls & Sandstones. Magnesian Limestone.	South Devon. Durham.
TRIASSIC	Bunter Pebble Bed & Sandstone. Keuper Sandstone; Rhaetic Beds.	Leicester Sidmouth. Elgin. Gloucestershire.
JURASSIC	Lias. Oolites. Oxford Clay. Corallian; Kimmeridge; Portland & Purbeck.	Lyme Regis. North Yorkshire. Bath. Oxfordshire. Dorset. Somerset.
CRETACEOUS	Hastings Beds; Weald Clay Greensand & Gault; Chalk.	Kent. I. of Wight. Downs and Wolds of England.
EOCENE	Woolwich, Reading & Thanet Beds. London Clay Barton, Bagshot & Bracklesham Beds.	Thames Valley London. Isle of Wight.
OLIGOCENE	Osborne & Headon Beds; Bembridge Beds Bovey Tracey Beds.	Isle of Wight. South Devon.
MIOCENE	Absent.	...
PLIOCENE	Coralline and Red Crags; Lenham Beds.	Norfolk and Suffolk. Lenham (Kent).
PLEISTOCENE & RECENT	Norwich & Younger Crags. Cromer Forest Bed. Till or Boulder Clay. Gravel & Alluvium.	Cromer. Holderness. Macclesfield. All stream valleys.

Pl. 4. *A* 4.

Table of British Strata, in Chronological Order (p. x.).



Pl. 5. *B* 5.

Vernal Fall, Yosemite Park, California (p. 6).

create these gentle outlines are by no means strangers; let us glance at them for a moment, before discussing their work in detail.

THE SHAPING TOOLS OF NATURE.

First, there is frost, which breaks up the surface; then all kinds of burrowing animals (especially the humble earthworm), since they perform a like duty; then rain, which sweeps the loose soil into streams; wind, the capricious builder and destroyer of castles of sand; and springs, whose underground courses have dissolved large quantities of rock beneath the surface, and whose insidious seepage causes landslips wherever a porous rock, like chalk, overlies a slippery and impervious one, like clay. Whether they act singly or in unison, these agents are all in a gigantic conspiracy to level the heights and fill up the hollows of the Earth's surface. It is true that they labour slowly; but their work is never ended, while there remains a scarred mountain peak, or a noble hill, or even a gentle rise in the ground; and no human agency can impede it for more than a moment. Twenty or thirty years, so much in a man's life, are to these humble but industrious toilers no more than the passing of a shadow across the sundial of time. And yet, under favourable circumstances, they can work almost as swiftly as man himself, whilst exceptionally (as in times of heavy floods) their destructive activities far surpass all human efforts. The effect of repeated sudden cloudbursts or "spates" on a Scottish hillside has been known to deepen a shallow sheep drain into a gully 10 or 15 feet deep, in the space of only six or eight years (1).* In the 'eighties, an Argentine market gardener made a shallow ditch opposite Ibicuy River, on the lower Parana, to take his produce by canoe to a main waterway. The Parana itself took this man's work in hand, and now ocean

* All references to authorities for text statements will be found on pages 351–358

steamers pass through the "Canal de Mercader" on their way down from Rosario (2).

It must be understood that, although valleys which have been excavated mainly by rivers are exceedingly common, they are by no means the only ones. We will refer to some other kinds a little later.

Building up Deltas.

Retracing our footsteps down our imaginary vale, let us pursue the river to its mouth—through rocky gorges; over precipitous falls, the recession of whose edge is well attested by the massive blocks of rock at their feet (Plate 5); under ivied bridges; past long, monotonous, reed-bordered flats; through busy towns; and over weirs to where the yellow tidal waters meet the sea. Much of the land is travelling with us; for, in addition to the visible mass of silt which discolours the water, and the dissolved matter which gives it its taste, there is a constant movement of the river bottom in the same direction; the sand and gravel being lifted up by the current and dropped again a few feet farther on: thus, the bed of the river literally hops to the sea. At the end of our journey, the mud-laden stream, checked by a wall of salt water, has its velocity greatly reduced, and can, therefore, no longer hold in suspension all the solid matter it has picked up *en route*. Much of the latter immediately sinks to the bottom, forming layer above layer, in regular beds, arranged like the leaves of a book, but in reverse order, for the last is, of course, the uppermost. The finer and lighter particles drift about for a greater or lesser space; but eventually they, too, come to rest on the bed of the sea.

This constant deposition of sediment at a river's mouth is the familiar process of delta building. The layers, or strata, form a permanent record of the river's doings, and also, in part, of the amount to which it has worn away the land; and they vary, both in nature and in thickness, with seasonal changes. They also serve as a burial-ground for all sorts of estuarine and shallow-water marine shellfish or molluscs, as well as logs of drifted wood, twigs, leaves, and even the bones of animals which have become mired in the marshes.

Delta deposits form a very large part of the Earth Book, mainly because of their special aptitude for preserving organic remains. Many things, however, may happen to the original deposits before they finally become available for human observation. They may be scoured by strong tides, and much of their mass distributed over the neighbouring sea floor; may grow, rapidly and undisturbed, into great flat projections of marsh land, whose bright green surface of waving reeds hides a treacherous and fetid slime; may then subside, and be covered by other similar beds; or may form migrating islands in the river's mouth, changing their shape and height with every freshet. No matter what happens to them, however, there is, in every case, a tendency to lengthen the mass of habitable land, and to decrease its height.

Measuring the Destruction of the Land.

We have already hinted that the creation of hills and valleys, though as a rule exceedingly slow in years, is yet more rapid than is generally imagined; while in special cases it may be such that noticeable effects are produced, even within a single generation. Now, the rate at which the land is being worn away can be directly ascertained, by computing the amount of matter which is annually removed by or into the sea; and in the case of rivers, observations of this nature have been conducted for many years upon a number of important waterways.

There are three kinds of matter constantly being removed from the land by streams, to wit: that which is visibly suspended in the water; that which is carried along on the bottom; and that which is dissolved by the chemical action of the water and its contents, and removed in solution. The last, though invisible, is at least equal in importance to the first; for every river carries some lime, iron, potassium or other easily dissolvable mineral, no matter how clear or tasteless its waters may seem. In fact, it has been estimated that the sea thus receives annually no less than 5,000 million tons of dissolved minerals alone (3), 157 million tons of which is common salt (4); and some scientists hold that nearly all the salt of the ocean has been derived from the land in this way.

The amount of removal accomplished by any particular stream depends, not only upon its size, but also, in great measure, upon the nature of the rocks it traverses: those streams whose course runs through soft sandy and limy rocks removing far more matter, bulk for bulk, than those which drain hard crystalline rocks. The Thames—a very small river indeed—empties into the sea each year over half a million tons of dissolved matter (5). The Nile pours annually into the Mediterranean some 50 million tons of suspended matter alone (6); while the Mississippi, the longest of streams, with branches traversing rocks of every character, pours into the Gulf of Mexico every year over 500 million tons of matter, suspended, dissolved, and carried along on the bottom (7). Taking the last as an example, and assuming that the average volume of the waste is about 120 lbs. per cubic foot, we shall find that the Mississippi basin alone loses annually a mass of rock one mile square by 340 feet high, or in one hundred years a mass 105 feet high, 30 miles long and 10 miles wide. If loaded into ten-ton railway trucks, the debris of one year's action would form a girdle that would encircle the globe nearly six times. Nor is this abnormal. The Amazon at Obidos has been estimated to carry seawards each year some 618½ millions of tons of suspended and dissolved matter; while the Paraguay, 20 miles wide and 20 feet deep when in flood, is certainly not far behind these figures. That the aspect of the globe is not altered materially from *year* to *year* by this great wastage is due, of course, to the relative uniformity of the action over the whole basin. Hence arises our conception of the slowness of natural changes—a false conception, because it is based upon purely human standards of time. There are no clocks in nature.

Rivers and Scenery.

This is not a book on the origin of types of scenery, or we could profitably devote some space to showing how rivers influence the form of a landscape, by seeking out the relatively weak rocks—clays and soft sandstones—wherever possible, and leaving the harder, more consolidated rocks as ridges between the watercourses; how they build up great plains in the middle of a continent, and then proceed, with errant and seemingly purposeless energy, to demolish those very plains, and rebuild them nearer to the sea. Enough has been said, however, to indicate that river waters work mighty changes upon the face of the Earth.

The Work of the Wind.

Another great toiler of nature is the wind, which daily transports vast clouds of sand and dust from place to place. It also uses this dust, under favourable circumstances, as a kind of improvised glasspaper, with which it scours and rubs away the surfaces of rocks.

Wind-and-dust action is essentially local, since it depends in a large degree upon geographical peculiarities. Nevertheless, it may cover vast areas; for some 25 per cent. of the Earth's land surface is a desert, and on that account especially susceptible to the invisible sandpapering. In its destructive aspects, the general tendency of wind action is to form vast shallow hollows, scooping out the sand, and piling it up in dunes along the rims of the depressions. The dunes then travel more or less rapidly, according to the prevailing direction and strength of the wind, spreading their destructive influence far and wide. Instances of destruction by dunes are extremely numerous, *e.g.* old towns in the Taklamakan Desert have been buried; while the date palms in the oases of Arabia are constantly struggling to avoid a like fate. So far as it has been observed, the rate at which dunes move varies from nothing up to 60 or 70 feet per annum; of which as much as two feet may be accomplished in an hour's work by a strong wind (8).

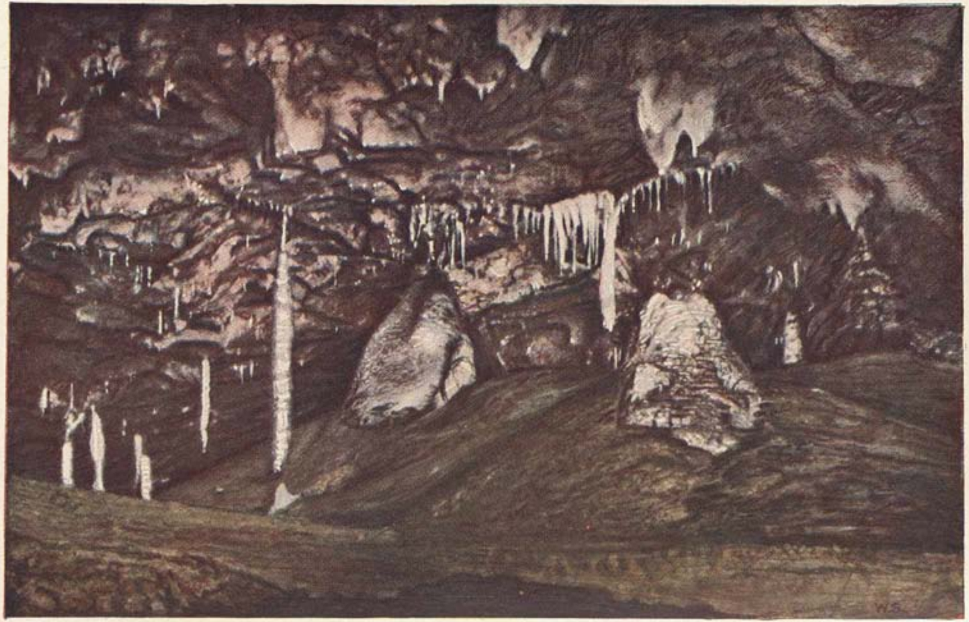
Winds are also partially responsible for the varying rates at which different parts of the Earth are being worn away; for if there were no winds, the moisture which is daily sucked up from the sea would, of course, fall back into the sea. As it is, the mutual relations between the atmosphere and the relief of the Earth cause more rain to fall on hills than on plains, and more on mountains than on hills (*cæteris paribus*); so that, in a very general sense, we may almost look upon the wide plains of the Earth as hardly undergoing sensible alteration, even in long periods of time, while the scarred and storm-swept mountains change literally from year to year. In regions that have no drainage to the sea, the waste from the mountains slowly fills the valleys: Arizona, Nevada, and Tibet are full of such "seas of rock."

Ice, Nature's Cold Chisel.

A third great weapon in nature's armoury is ice. Aided by its powerful auxiliary, frost, its action resembles that of a multitude of small chisels, levers and files. Nearly all elementary bodies respond to the influence of heat and cold, by expanding under the one and contracting under the other and

Pl. 6. *B* 10.

Ghost Glacier, Mt. Edith Cavell, Alberta (p. 12).



Pl. 7. *B* 11.

Kent's Cavern, Torquay (p. 14).

Stalactites hang from the roof, stalagmites rise from the floor.

to a very great extent this is true of their compounds. The results of this motion are particularly apparent in the case of rocks, on account of their brittleness and of the rapid changes of temperature to which they are subjected, the component grains of the surface layers falling away into dust. Let us, in fancy, travel to some lofty mountain area, where the days are hot and the nights cold, such as the High Alps or the Himalaya. Here, large areas of bare rock are alternately baked by day and frozen by night; and the moisture, which is there unusually abundant, adds to the disintegration of the surface. The fierce noonday heat, dissolving the snow, causes runnels and films of water to soak into the rocks; the cold of night freezes all again; and, owing to the expansion of the water on assuming the solid state, any irregularities which may dot the surface are forced apart, and strong wedges are driven into every crack. Thus, innumerable roughnesses are chipped off. Their removal by a thaw paves the way for another attack. Alternate expansion and contraction causes fresh cracks to form; and so the process goes on. It is the same in high, arid regions, where diurnal changes of temperature effect similar results, without the aid of much moisture. The results of such decay are so apparent that boulders of granite can be crumbled into sand between one's fingers. I have seen places in the barren deserts of Western Peru where the whole visible surface of the "granite" was composed of disintegrated blocks.

GLACIERS.

More impressive (though really less destructive, because their action is confined to special localities) are the huge ice rivers, or glaciers; which, fed from gleaming white snowfields high up among the peaks, slowly creep in white lines down towards the valleys; ending, often well below the general snowline, in mud- or earth-covered snouts and turbid lakelets

If we step upon the surface of one of these glaciers, we shall find it far less white than it seemed from a distance; for in places, and especially near the snout, it may be completely coated over with mud and rock fragments that, having fallen from the cliffs near the glacier's source, have been transported on its surface in long, hummocky lines for a distance of perhaps many miles. This debris, which is generally composed of very miscellaneous and angular stones, from the finest chips to boulders as large as a cottage, has a passing resemblance to the rubbish shot out of some gigantic housebreaker's cart; and in favourable localities, such as the Hispar Glacier, in the Himalaya, it may form steep mounds one, two or even three hundred feet high around a core of ice (9). As the glaciers may be anything up to thirty or forty miles long, the great amount of rock removal which goes on in this way needs no comment.

Another important function of glaciers is the scouring away of the bottoms and sides of their basins. Innumerable stones and boulders become frozen into the base of a glacier. The ice, moving down from its source by the action of gravity, and carrying on its under surface this immense natural rasp, strips the underlying rock of every vestige of soil or subsoil, and polishes the surface so beautifully that the rainstorms of thousands of years may fail to remove the marks. The temperature at the base of a glacier is just above the freezing-point, which enables streams to form from melting cracks; and these streams pursue weird and snake-like courses under the ice—not always downwards, like ordinary streams, but across vales and gullies, and sometimes even uphill. They aid the work of destruction by cutting into the floor and removing masses of smaller fragments, fine silt, and the like.

In addition, there is a continual plucking away of the rocks at the base of the glacier's head, which gives the surrounding mountains the aspect of a huge amphitheatre or *corrie* (Plate 6).

AVALANCHES.

Ice is seen in its most terrible form in the guise of avalanches. Vast masses of snow become perched in insecure positions, high up among the crags; and only a little melting is sufficient to send many thousands of tons hurtling down into the valleys. These gather weight and volume as they fall, carrying down in their headlong career great quantities of stones of every conceivable shape and size. When the avalanches descend into a valley that is occupied by a stream, they are frequently of sufficient magnitude to dam the rushing waters; the latter pile up in concentrated fury, until their weight is sufficient to move the obstruction; the dam then bursts, and widespread desolation for miles down the valley tells of the furious flood that has scurried through it.

THE RESULTS OF ICE WORK.

All the above efforts of frost and ice remove, between them, so much rock waste from the mountains, that in the spring (when glaciers, on account of their own winter accretion and the sun's greater melting power, are most active) the streams issuing from their snouts are often incapable of transporting all the debris; and this latter is consequently spread out in fan-shaped masses, composed almost entirely of gravel, sometimes over a very large area. The results of the work are also well shown in the shape of a valley which has formerly been occupied by ice, or glaciated, but which is now, through climatic changes, restored to its normal condition. Such valleys are more or less U-shaped, whereas the profile of a normal valley is a V; the difference between these two outlines is a fairly just indicator of what has been accomplished during the time of glaciation.

Springs; Underground Streams (Plates 7, 9).

One would little think that the bubbling spring, so cheerfully gurgling its welcome on hot and dusty days, could be in the natural conspiracy of land destroyers; but it is, and no worker is more influential in limestone regions. The air we breathe contains a minute quantity of carbonic acid gas. This is carried down into the earth by rain-drops; and the acid, which has the power of dissolving limestone, has eaten so much into considerable tracts of the Earth's surface, as to make them practically worthless to man. By percolation through the joints and cracks in the rocks, innumerable caverns and underground rivers are formed, and enormous quantities of dissolved limestone are carried away, through springs, to the sea (Pl. 7). This solution of limestone, so simple in itself, has vast and wonderful results. Most of the lime in sea water is derived in this way, the remainder resulting from wave action on cliffs. This lime is secreted by molluscs to form their beautifully fashioned shells; it is also the most important constituent of coral reefs.

The most obvious results on the land are subsidences of greater or lesser extent in limestone regions. For instance, a great area on the east side of the Adriatic is intricately honeycombed in this way. "The whole surface of the country is everywhere pierced with deep boat-shaped cavities, at the bottom of which the water forms a kind of whirlpool, like the water flowing out of the hold of a stranded ship. Many mountains are penetrated in every direction with caverns and passages, just as if the whole rocky mass was nothing more than an accumulation of cells" (10). A similar area runs in a long band across the south-eastern United States; and smaller ones exist in many other places, particularly in the East Indies, in the Jura and in Greece. Of the same nature, but of trifling extent as a rule, are the numerous swallow holes in our own chalk lands. Some

Pl. 8. *B* 14.

Curious Land Sculpturing by rain in Southern Utah (p. x).

Pl. 9

B 15.

Umi-Jogoku ("Sea-Hell"), Japan (pp. 14-15).
An acid vitriol hot spring—400 ft. deep—temperature 195°F.

of the caves which are formed by this solution of limestone attain the most imposing dimensions. Thus, the celebrated Mammoth Cave, in Kentucky, has about 217 *miles* of passages (11); while the equally famous Grotto of Antiparos, 600 feet below the earth's surface, is 300 feet wide and 240 feet high.

Whence comes all the other mineral matter, apart from lime, which is found in springs? Almost all of it is certainly derived from the rocks through which they pursue their tortuous courses; but a very small proportion of springs come from such deep-seated sources as to preclude the idea of their having been derived originally from surface waters (12). The total quantity of matter that springs bring up, though not measurable, is certainly enormous.

One other remark on this interesting branch of our subject. The addition of any mineral to the water converts it into a more or less powerful chemical solution; and as one mineral after another is dissolved, constantly differing chemical reactions take place between the solution and the walls of the fissure through which it passes. Here, again, a thing which in itself seems trifling is fraught with the most important consequences to human beings; for many of the world's most valuable silver, copper, lead and other economic deposits owe their value mainly to these percolating solutions having either removed their impurities, or, by depositing the pure metal, added to their richness.

THE SEA.

Finally, we come to the greatest destroying agent of all, the sea; that mysterious, rolling expanse, the very name of which brings salt to the nostrils. Man, in his progressive advancement, has mastered almost every force of nature, except the sea. Let it be angry, and his groynes cannot check it, nor his strongest ships ride upon it, but at their peril; let it be calm, and no lever of human achievement can move it one iota. It is a world in itself, as great as it is little known. And yet, when we survey it from a sufficient mental distance, it is but a bowl of water; and all its motions can be brought into play by breathing upon the surface!

Its destructive effects upon the land are sufficiently obvious to be dismissed in a few words. These effects are best manifested upon the margin of the ocean. Those of us who pay repeated annual visits to one particular seaside resort must have noted how, in minor details, the coastline alters practically from year to year; such and such a rock is there no longer, or a once dangerous cliff has fallen, and so on. The rapidity of the changes is due to the efficient combination of nearly every natural destroyer in the work. For wherever cliffs rear proud walls against the ocean, rain, springs and burrowing animals may get to work; and wherever the tidal waters wash the base of the cliffs, the force of the breakers drives wedges of compressed air into every nook and cranny, smoothing away all natural irregularities, and tending to bring down overhanging masses from above (Plate 10). The place of beach pebbles in this marine assault is a varying one—sometimes helpful, acting as a barrier against further encroachment; sometimes destructive, as when the waves hurl them like small artillery upon the rocks. All the numerous daddy's holes and gloomy, salt-smelling caves; all the tall cliffs and smooth, weed-lined curves below high-water mark which dot our shores, are the results of these various activities. The amount of matter which is removed from coasts in the course of a year must reach an exceedingly great figure. By way of compensation, however, the sea is for ever building up in one place what it pulls down in another; and in England, at least, there is a larger *area* gained than lost, although the *volume* of land gained is not so great (13).

Erosion on the Bottom of the Sea.

Besides this, its visible work, the sea is for ever engaged in labours of whose existence most of us are blissfully unconscious. To a depth of several hundred feet, and in favourable localities much deeper, the ocean currents have a considerable power of modifying the shape and constitution of the sea bottom, by removing excrescences and filling up hollows; while in funnel-shaped estuaries, such as the Bristol Channel or the Bay of Fundy, and in shallow straits, the scour of the tides moves incalculable quantities of matter, distributing it over the deeper areas around. In exceptional circumstances, even as far down as 6,000 feet, the currents are strong enough to effect this removal of soft sand and mud; for the bases of coral islands in the Chagos group have clean rocky surfaces at that depth; all the waste from the adjacent shores, which in the ordinary course of things would accumulate thereon, having been swept out into the deeper abysses of the Indian Ocean (14). A similar condition of things prevails in the deep water off the Azores (15).

Natural Checks upon Land Destruction.

One could multiply, almost to infinity, instances of the destructive work of natural agencies; but enough has been said to demonstrate their existence and the general character of their operations. The obvious conclusion of their work, were they left to carry it on without let or hindrance, would be the conversion of the Earth's surface into a waste of waters. But, happily, there are numerous other provisions of nature, whereby the land is preserved from submergence; and these checks may retard the work of the levellers to an almost indefinite extent. Such preservative agencies are: all forms of vegetation, but especially forests, which preserve the surface from destruction by rain or wind, and grass, which binds the soil with a closely-knit mat; lakes, whose still, calm waters force the mountain torrents to disgorge their weighty loads of sediment, and release them again as clear, smooth-running and comparatively harmless streams; reef-building corals, which erect a land surface much faster than the waves can destroy it; and, of course, the protective effect, under certain conditions, of the very agents which are most active at destroying the surface. The last item is many-sided enough to warrant our adducing a few examples.

For instance, springs sometimes build up very considerable mounds, and even hills, by the deposition of their solid contents at their mouths, usually in the form of travertin or calcareous tufa. There are numerous beautiful examples of this, particularly in Italy, Germany, Algeria and Asia Minor. In a lonely part of Ionia is a mass of white travertin, known as the "Castle of Cotton," no less than 328 feet high and 2½ miles wide, which has been formed entirely by the agency of local springs (16). A Roman legend has it that in this district, if a proprietor of land wished to enclose his domains, he caused a current of spring water to run along the boundary line, and in the space of a year the walls had risen. To give only one other instance, the well-known and beautiful sinter terraces which are found in regions of geysers or hot springs, are nothing but the resolidified silica brought up in the thermal waters. The famous spring of Louèche, in Switzerland, has been estimated to bring to the surface every year nearly 9 million lbs. of gypsum (17)—a mass, that is, 1 yard high, 1 yard deep and nearly 1¼ miles long.

Wind, again, very generally builds up dunes on sandy shores, which, where there are suitable embayments and the winds are constant in direction, are often driven in straight lines across the bays from promontory to promontory, converting all the water on the inner side into lagoons. Once such a barrier has been created, the active growth of marsh plants, and the blowing of fresh sand into the lagoon, combined with the masses of silt brought down by the streams, gradually converts the whole embayment into land. Striking instances of this combined action, in which the ocean also takes a powerful hand, are shown all along the east coast of North America, and by Dungeness and the Chesil Bank in our own country.

The most important re-creation of land from its destruction, however, is in arid regions, where the waste from the mountains builds up plains across the valleys that are incessantly rising, a slow tide of debris, around the peaks whence the detritus came. Such deposits are very commonly red.

VERTICAL EARTH MOVEMENTS.

Despite all this, if we carefully weigh the opposing forces together, we cannot avoid the conclusion that in the end they must lead to the destruction of all land surfaces; and, but for one thing, the Earth would eventually become uninhabitable except by marine animals. That one thing is an extraordinary and still wholly unexplained vertical movement of the Earth's crust. Operating after the manner of air bubbles beneath a tablecloth, it is for ever elevating here and depressing there large or small areas of the surface. This vertical movement, which is measured in relation to sea-level, is exceedingly well attested all over the globe; in fact, it is principally on this account that we know anything at all about the world's past history. There are, for instance, many places where the rocks are of a muddy or sandy nature, bearing every evidence of having been laid down in shallow water—ripple-marks made by the waves, sun-cracks, and even the impressions of rain-drops. Scattered among the layers is also a goodly assemblage of fossil shells, the living representatives of which all dwell in shallow, brackish water such as is found in estuaries; there are also fragments of wood, leaves, the hard fruits of trees and, less commonly, the bones of animals that have been washed out with the tide. These remains persist through thicknesses of anything up to many hundred feet; thus clearly indicating that throughout the time of their formation, the estuary wherein they were laid down was slowly subsiding. Now, such beds as these are found at all imaginable altitudes; and other beds, such as marine limestones, full of fragments of corals and the like, form the summits of some of the highest mountains on the globe. No hypothesis can be framed to account for their present position or for their origin, without calling in subsidence to create the beds, and elevation to explain their present situation.

These subsidences and elevations are in progress now. They have been for a long while measured and observed, as we shall show hereafter, although their rate is slight—perhaps only two or three inches in a century. They may continue, with pauses, until rocks which could once be seen from the surface through the shallow water, lie beneath many thousand feet thickness of younger rock layers, or until one-time coastal plains have risen into the semblance of mighty plateaux.

The effects of these movements are best manifested on coasts, because there they attract most attention; but they are just as evident in inland areas, and they occur with equal certainty beneath the sea. We shall deal with them further in a later chapter: it must suffice to refer here only to a few examples.

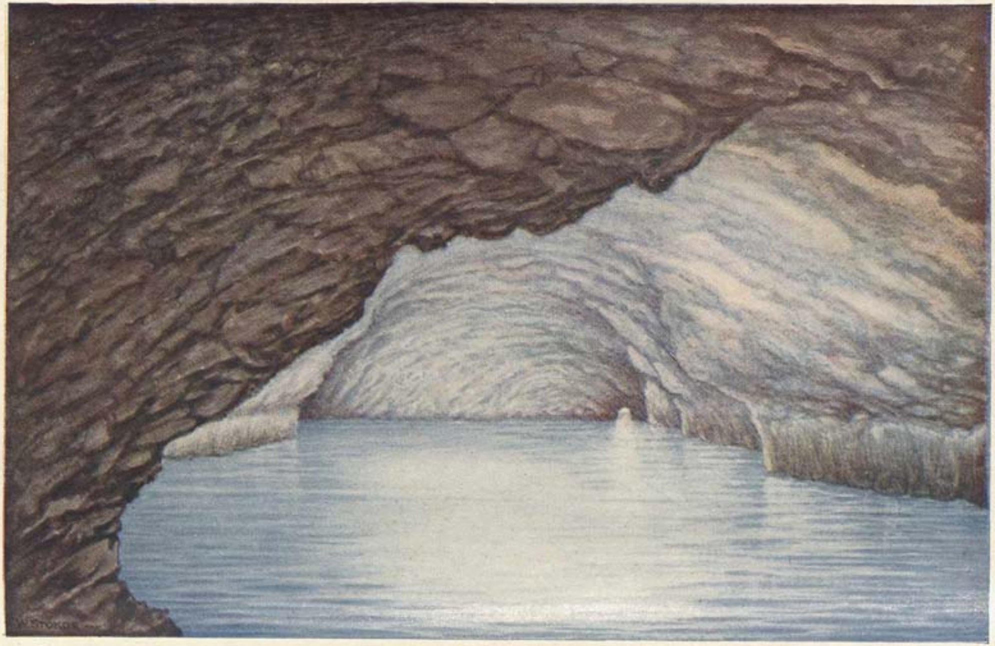
Recent Elevations of the Land.

The beautiful Bay of Naples has undergone several vicissitudes of this nature, even since Roman times. Amongst other proofs, the Blue Grotto, in Capri (Plate 11), which was used as a bath by the Romans, now has the roof of its entrance

Pl. 10. *B* 20.

Coast near Bude, Cornwall.

A striking instance of wave battering (p. 16).



Pl. 11. C 21.

The Blue Grotto, Capri (p. 20).

reduced almost to sea-level; the roof of a former entrance is about 8 feet below the sea; while a flight of steps that once led down to the water now continues some 20 feet below its surface (18). It is the singularly beautiful appearance of this cave, when seen by the transmitted light, that has made it one of the most delightful sights in nature. All along the coast in this region, too, is a narrow wave-cut notch, of fairly recent origin, 12 to 23 feet above the sea, which represented its level in post-Roman times; when Tiberius was alive, on the other hand, the Blue Grotto and other subsidences show that the coast was some 20 feet *higher* than at present (19).

As, however, the Neapolitan district is a volcanic one, and peculiarly liable to disturbances of level, we must adduce a few other instances, in places where no such influences are known to exist. Thus, on the eastern coast of North America there has been a distinct see-saw motion, during the last few thousand years, through an axial line which runs latitudinally across the State of New Jersey. All the area about Chesapeake Bay is a deeply drowned system of river valleys; the valleys of the Hudson and Connecticut Rivers, on the other hand, show former shorelines at higher and ever higher levels the more to the north one goes.

The steady rise of the coast of Sweden in recent centuries is noted in every geography book. This is another instance of see-saw motion; for the rise is greatest in the extreme north of the Baltic, where it is between 3 and 5 feet per century; while at Stockholm there is very little motion, if any; and Malmoe, in the south, sunk 5 feet 2 inches in about 140 years (20). These rates are abnormally rapid.

In many parts of the Scottish coasts, there are traces of three distinct terraces, approximately 100, 50 and 25 feet above the sea. These, which mark different levels of the strand-line, are all younger than the youngest event in geological history, the Ice Age. On the other hand, the whole of the south-eastern and southern coasts of England have sunk between 50 and 80 feet during the same period.

Recent Subsidences of the Land.

The best examples of subsidence of coasts take the form of drowned river valleys. Besides those already cited, intricate systems of submerged valleys cover the fiord regions of British Columbia, New Zealand, Norway, etc. Submerged forests, such as those of the Bristol Channel and of Torbay (21), are also unequivocal evidence of subsidence; and the Roman buildings on the Tyrrhenian shore which are now awash and even submerged, must convince the most sceptical unbeliever.

The Land moves, not the Sea.

One might possibly assume, that because the Earth appears stable and the sea unstable, it is the sea which has moved; but if a number of adjacent areas of subsidence and elevation be regarded as a whole, it will invariably be found that if the sea is to fit in with all the various levels that it has occupied at any one time, then it must have a surface like a corkscrew. As a fact, the surface of the sea is *not* quite level; since, by the action of gravity, its waters tend to pile up near high mountain ranges—as, for example, where the Western Andes approach the Pacific; but this variation is trifling, and cannot account for any of the phenomena with which we are at present dealing. It must be accepted as a fact, then, that the land, so seeming solid, actually does move up and down; and now comes the question, why? It is exceedingly difficult to answer. Hypotheses of greater or less plausibility have from time to time attracted attention; but none of them meet all or even most of the circumstances. A popular, because easily understood idea is that the Earth's interior, beneath the level of a few miles, is sufficiently plastic or molten to be sensible to variations in pressure from above; so that where sediment is deposited, subsidence may be looked for; and conversely, where it is removed, we must expect elevation. This variation in the load which the inner Earth carries is undeniably a factor in the case; but, unhappily for the *isostatic* theory, many areas are indisputably sinking where nothing is being deposited, and others rising which are receiving loads. In areas of volcanic disturbance, such as Naples, where the molten reservoirs are relatively near the surface, the action may be partly due to the restlessness of the subterranean lava, in others, it is still a mystery. *See* page 68.

FOLDS AND FAULTS.

The vertical movements are one prime cause of a phenomenon which we shall frequently have occasion to observe—to wit, the folding and faulting of rocks. In many a cliff or railway cutting we may observe the rocks to be curved into arches, or even sinuous wavy lines, as regularly as if they were made of plastic clay (Plates 12, 34). This is due to pressure, applied from one or both sides, or from below, or from a combination of all three; and the rocks have been buried beneath such heavy loads at the time of folding that, in many instances, they have actually behaved just as clay would do under like circumstances. Differently coloured ribbons of wax in a box with a movable end have been made, by experiment, to give precisely similar results.

In numerous cases, strains operating upon alternations of hard and soft rocks have affected them unequally, the soft rocks tending to bend and the hard ones to break. When a break occurs, and there is the slightest displacement of the two sides of the broken rocks, it is called a *fault* (Fig. 2). Sometimes, when the rocks have been folded back upon themselves, the pressure has been so great that they have parted at the junction of hard and soft layers, and the former have been thrust bodily over the latter for distances up to several miles; a break of this nature is called a *thrust fault*. As faults play a very important part in earth history, we shall have to notice them a little more closely; the more so as fault lines are intimately mixed up with earthquakes.

VALLEYS DUE TO FAULTS.

The commonest evidence of faults on the surface is, perhaps, to be found in the existence of valleys. Many dales follow, more or less closely, lines where the solid rocks have been fractured; because these are the weakest parts of the surface, and therefore most readily attacked by running water; and once lines of drainage are established, they are not easily removed. Some valleys are almost entirely due to faults; the base of both valley walls being a line of fracture, and the space between having been let down bodily. In all such cases there are cross fractures at various angles to the main ones; by means of these, the valley floor is divided up into a number of subsided blocks of land (Fig. 2). Some of the major features

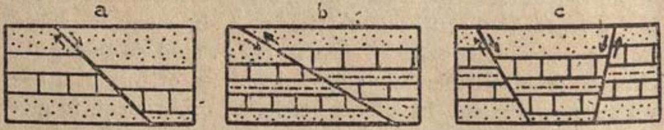
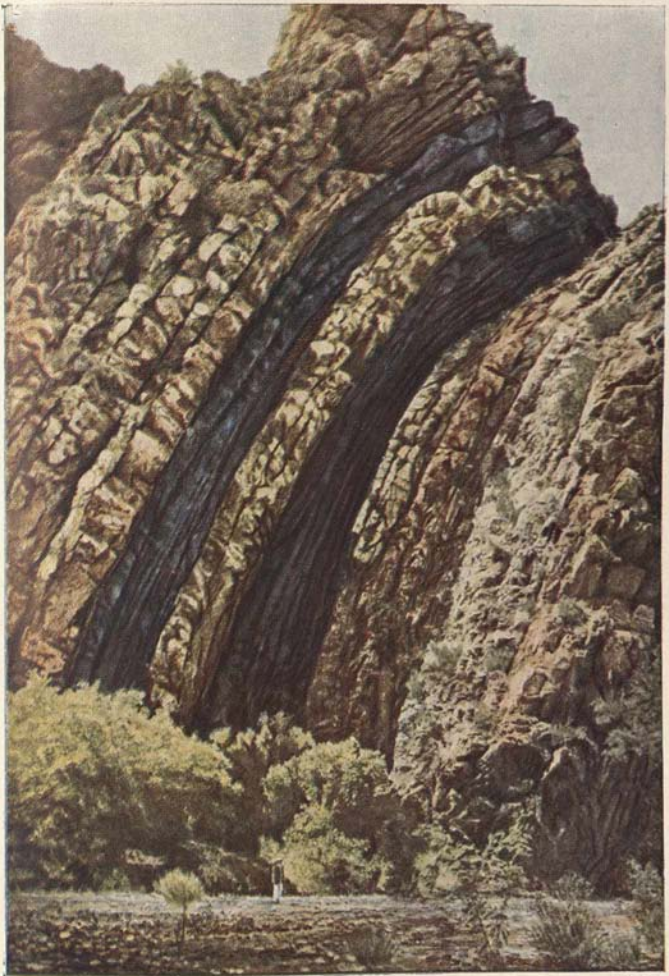


FIG. 2.—Faults: (a) normal; (b) overthrust or reverse; (c) fault block.

of the globe are due to this kind of faulting. For instance, many valleys in the North American Cordillera are caused by it; and in particular, a profound depression, running for nearly 1,000 miles, from Alaska to Utah, on the precipitous border of the Rocky Mountains, is known, from its ditch-like aspect, as



Pl. 12. *C* 24.

Folded Rocks near Montague, C.P., South Africa (p. 23).

(Photo. S.A. Govt. Rlys., Publicity Dept.).

Pl. 13. *C* 25.

Balance Rock, Rhyolite Park, Arizona.

the Rocky Mountain Trench. The great African Rift Valley, ramifications of which extend from the Great Lakes across Somaliland, up the bed of the Red Sea and through to the Jordan, is another outstanding example; Spencer's Gulf, Australia, is a third. In all these cases, it must not be imagined that the furrows were created in a moment. They probably came into being with extreme slowness; their depth being the result of constant small slips along well-established lines of weakness.

But there are faults and faults. At the other end of the scale are many which, although they may have attained considerable magnitude, yet do not affect the superficial aspect of the globe at all; besides a vast number whose detection is often a matter of extreme difficulty. Such faults as these may be found almost anywhere.

THE NATURE OF EARTHQUAKES.

We have purposely refrained from mentioning before, two weapons of change in nature's armoury which have, at times, exercised a very potent influence on the affairs of the Earth, because their power is local and spasmodic, rather than general. We refer to earthquakes and volcanoes.

The literature of earthquakes alone comprises thousands of volumes, of many different kinds and sizes. Now, if we imagine all these tomes to be stacked in masses, the bulk lying in horizontal attitude, but others tilted at various angles up to the perpendicular: some with torn covers, bent into close curves; some solid and heavy, others paper-bound and light, and the whole resting on a very strong floor: we can get a passable idea of what rocks a representative section through the Earth's crust will show. The instability of such a pile is self-evident; for there are various places in it where heavy books tend to slip upon or override lighter ones, on account of the weight which they themselves have to bear; and then there are numerous spaces large enough to permit of movement among the nearest books. Let us assume that a slight pressure is applied at any one point, in any direction whatsoever; the result will be alteration, or a tendency to it, in the position of the nearest books; and this is transmitted from one to another until a point of weakness is found, when a readjustment takes place. The actual area readjusted may be trifling. Its effect, however, is shown, not only in its immediate neighbourhood, but also over a considerable number of the surrounding tomes, by a slight trembling due to the shock. Of such a nature are earthquakes. Caused by lack of uniformity in the rocks below the Earth's surface, combined with variations in the pressures which those rocks have to sustain, they are the visible expression of their efforts at re-establishing equilibrium by relieving strains; and although there is very little known, even theoretically, about the interior of our planet, we can confidently assert that there exists a zone, within some twenty miles of the surface, in which readjustments of this nature are constantly taking place. It is a very significant fact, that one half of the ten thousand earthquakes, large and small, which are estimated to take place every year, are on the steep submarine slopes bounding the continents, which run down to the oceanic abysses at the relatively high grade of from 1 in 20 to 1 in 30 (22).

The origin of volcanoes is believed to be very different from that of earthquakes; for, although the two are often observed to act, as it were, in conjunction, the greater or world-shaking earthquakes appear to have no direct connection with volcanic disturbances (23).

THE EARTH'S INTERIOR IS INTENSELY HOT.

Now, many years of careful experiments in deep mines and wells have established the fact that the Earth's temperature steadily increases with the depth from the surface; and this law holds good to the greatest depth to which man has attained. The rate of increase varies from 1° Fahr. for every 30 or 40 feet to 1° for every 130 or 140 feet. Thus, deep mines have temperatures constantly equal to summer heat, be the conditions at the surface what they may. It is fair to argue that the increase in temperature does not stop at the deepest point that man has attained to, but that it goes on in a definite ratio far beyond that point. On the ground of general probability, coupled with numerous cuttings through old and once deeply buried crystalline rocks which are now exposed at the surface, it has been inferred that at no great depth—certainly under 50 miles, and possibly at less than half of that—all substances known to us must be in a molten or gaseous condition.

For example, granite (which, though common at the Earth's surface, is of subterraneous origin) is composed of crystals of different minerals; and by laboratory experiments it has been found at what temperature each of these minerals alone would become molten. Briefly, we may take this to vary from about 1,450° Fahr. to about 2,250°, according to the mineral (24): the former figure being that at which quartz crystallizes, and the latter that at which granite has been made to melt. Consequently, when the granite became solid, the temperature must have been rather under 1,450° (other things being equal); for had it been more, the quartz would not have crystallized. Owing to the peculiar behaviour of such molten mixtures, it is not possible to say in a word what the exact temperature was; but we can safely assume, when we look at a piece of granite, that it came originally from a spot in the Earth's interior where the heat was about seven times that of boiling water.

If we estimate that the rate of increase of temperature downwards averages 60 feet for every degree Fahr., then we must go down about 16½ miles to get such a temperature; but this figure should probably be doubled, to allow for the lower temperature at great depths. There the rocks are either molten or in a treacly condition. No borings have ever attained even a tithe of this depth: the greatest is only a mile and a half, in the Rand.

WHERE SOLID AND MOLTEN MATTER MEET IN THE EARTH.

But the figure we have taken is an *average*, whereas in nature the rate of increase varies greatly, implying that the border-line between solid and molten rock is very irregular. This irregularity, also, is increased by the heights and hollows on the surface; arching up under mountains, bending down under dales. There is thus obviously much more scope for the molten matter to attack and corrode areas of the solid roof above it, than if the line of junction were simply an arc of a circle. This is particularly evident where high mountains are close to submarine abysses; and it is a striking fact that such areas exhibit both volcanoes and earthquakes: in such localities, provided that the temperature gradients are constant, one would *expect* lines of weakness to arise. The intense heat of the molten matter would crack and disintegrate its roof; into every crack, large or small, fingers of molten rock would press; and if the pressure were great enough, fissures would be formed that would communicate with the surface. Actual exposures of ancient rocks prove that this action does take place.

ORIGIN OF VOLCANOES.

Up these fissures volcanic matter would be liable to come, whenever sufficient force, as of compressed steam, had accumulated to overcome the force of gravity. Thus, we should have a volcanic orifice: either a hole, a number of holes or a line of cracks. That such is the general nature of the reservoirs of many volcanoes, is conclusively shown by numerous beautiful examples in Canada and elsewhere, to be referred to later.

Now, steam is one of the most important constituents of lava streams, and also a terribly efficient and well-nigh resistless force when sufficiently compressed. It is steam which is believed to cause the rumblings that precede an eruption, when, as water, it comes into contact with very much hotter matter; the water itself may be derived from oceanic seepage, through cracks along the steep submarine slopes. When the explosions are very excessive, a way is cleared to the surface, up which, under enormous pressure, come great quantities of poisonous gases, ashes and molten lava, in the many terrible forms which are so well known as to need no special description. Professor Judd has aptly compared what goes on in the crater of an active volcano with the action of porridge when being heated:

"The glowing material seems to be agitated by two kinds of movements, the one whirling or rotatory, the other vertical or up-and-down in its direction. The fluid mass in this way appears to be gradually impelled upwards till it approaches the lips of the aperture, when vast bubbles are formed upon its surface, and to the sudden bursting of these the phenomena of the eruption are due" (25).

In other words, an eruption is merely Mother Earth blowing off steam, like a locomotive: in a very literal sense, too, for immense quantities of steam are ejected, occasionally being shot up to heights of 20,000 feet above the surface (26).

Volcanic Mountains.

The great volcanic cones whose majestic outlines command our awestruck admiration, are nothing but the refuse heaps of eruptions; being composed, from base to summit, of lava and ashes (Plate 17). Such an one is Fujiyama, one of the most perfect cones in the world; which, although it is 12,365 feet high, is yet so light in texture that it actually bends under the wind's pressure (27). Etna is a more solid and perhaps the best-known example of this type of volcano; Vesuvius, Popocatepetl, Teneriffe and Kilima Njaro are others. Occasionally, the height of volcanic cones is increased by pressure from below, without any more material foundation. Thus, after the eruption of Usu-San, in Japan, in 1910, a new mountain arose on the slopes of the old one, no less than 510 feet in one hundred days, only to slowly subside again (28).

Under certain circumstances, molten matter may communicate so readily with the surface, and may be so saturated with steam, that the lava just wells up through the fissures and floods the surrounding country with liquid fire ; the best-known example is Kilauea. These are known as fissure eruptions; they are apt to cause quite as much desolation as the ash-ejectors. They were far more common in the past than they are to-day.

The opposite result may be witnessed when the lava is so solid as barely to flow at all. Thus, in the great eruption of Mont Pelée, in 1902, a huge solid chimney, 800 feet high, was forced out of the crater after the main eruption (29), exactly as one would push up the lead out of a pencil. A very similar eruption took place in the Bogoslov Islands, in the Bering Sea, in 1906–7 (30).

Volcanoes under the Sea.

But the eruptions we witness, however terrible they may seem, are slight by comparison with others which are as constantly taking place, but which we never can observe—to wit, submarine eruptions. For there, often at depths of fifteen to twenty thousand feet, the twin demons of fire and water battle for supremacy, with no living witnesses except the silent sea lily or the tiny deep-sea fish ; and although the ocean smothers the internal fires, it cannot put them out, or even prevent them from ejecting their usual products—pumice, lava and steam. There are numerous instances, particularly in the

Pacific, of volcanic islands coming into existence in a few days, in what had previously been deep water. Conversely, an eruption in December, 1913, at Ambryn, New Hebrides, in the middle of that vast and lonely watery waste, converted the British Mission Station into a sea-bed some fathoms deep, while the former fishing grounds off the island became land. The disturbance which brought about this change so heated the water that fish came to the surface cooked (31). I have myself, off the Peruvian coast, more than once observed the discoloration of the water, and numbers of dead fish, as the result of some minor submarine eruption. Much of the floor of the Pacific Ocean is littered with the volcanic products (pumice and manganese nodules), while lava streams have also been proved to exist on the ocean bed.

CHANGE IS THE KEYNOTE TO EARTH HISTORY.

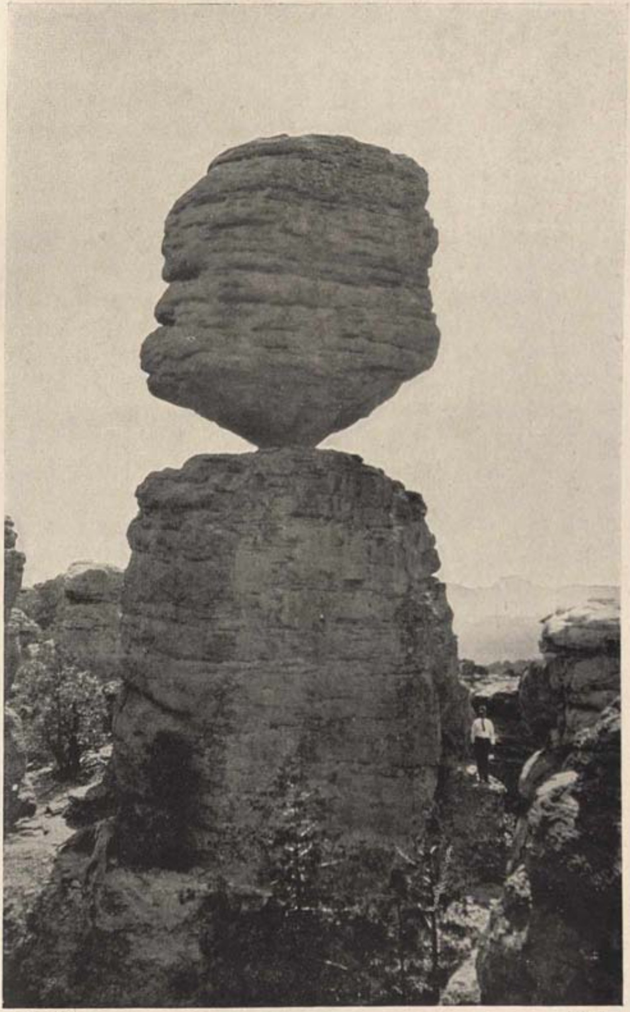
In the above brief introduction to our subject, we have merely sketched out the major lines on which natural evolution works its changes upon inorganic matter. We have endeavoured to make it clear that the aspect of the Earth is incessantly changing, in some places fast, in others slowly; and that of all those things about us which seem permanent and unalterable, not one but has been different in the past, and will be still more different in the future. The story of the Earth, upon which we are about to enter, is one long record of changes, similar in degree, and in kind, to those which are taking place to-day.

But the points we have emphasised are merely fundamentals. They are very far from being the sum total of changes. As the brain that directs the hand which is to strike a cue against a billiard ball is the starting-point for a long series of events, so is every change in the face of the Earth the precursor of changes in its inhabitants and its climates.

CHANGES OF CLIMATE, AND THEIR CONSEQUENCES.

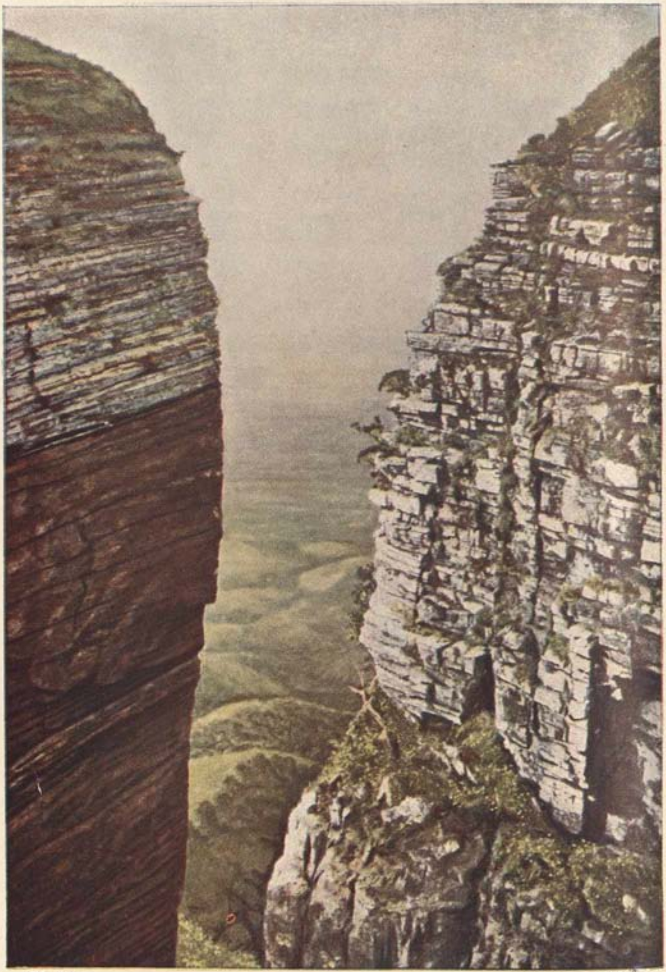
Consider the climate first. Now, the climate of any particular country is controlled, in the main, not so much by its proximity to the poles or to the equator, as by its proximity to the sea, its relation to other lands, and the relief of its surface. The mild climate of our own country would be a geographical freak, and the climate of Labrador more or less what one would expect in our latitude, were one to consider climate as ruled by latitude alone. As an island differs from a continent in having less extremes of heat and cold, and in possessing greater humidity, as well as very different organic beings, so would all those things change were the island to become an integral part of the continent. An alteration in the level of the sea-bed might divert some warm current from its shores : such a change would not only cause the coast to be laved by cooler waters, but blown upon by cooler winds. An increase in altitude would for a certainty tend to increase the rainfall ; a decrease might have an opposite result.

Then as to the living creatures. Everything has a special habitat, under which it thrives best, and to which it cleaves. Change the climate, and you change the inhabitants. Imagine, for example, a radical change in the geography, and consequently in the climate, of the Argentine. At present, this is essentially a long plain sloping to the east and south-east from the Andine chain to the Atlantic. The prevalent winds being from the east, reach the land soaked with moisture, and rain is plentiful, getting, however, less and less as one travels to the west. The mountain barrier wrings out so much moisture from these winds that they have little or nothing to drop in Chile, which is consequently, in the main, a desert. The myriad forms of animal and vegetable life which diversify the plains on the east of the mountains are strangely wanting on the west ; giving way to the cactus and lizard, symbols of a desert region.



Pl. 14. *C* 32.

Peg-top Rock, Rhyolite Park, Arizona.



Pl. 15. C 33.

The Devil's Window, Drakensberg, S. Africa (p. 23).

(Photo, S.A. Govt. Rlys. Publicity Dept.)

Now, let us conceive a new chain of mountains to arise, not in a night, but very slowly—humanly speaking—say, in a thousand years—which shall run from north to south across the middle of the Argentine plain; the winds and other factors remaining the same. It is obvious that this new chain would usurp the function of the Cordillera, in drying the winds; consequently, the space between the two chains would become as dry as Chile. All its animals, all its plants, would migrate or perish. In their places, thorns and dust would take possession; even man, most adaptable of animals, might find himself excluded, if there were not sufficient water. Conversely, let us, with a stroke of the pen, cut all these mountains off the map altogether. The small, rushing rivers of the west coast would gradually become deep, quiet streams, and Chile, by degrees, would fall into the semblance of its neighbour. From such an example as this, it is easy to see how the relief and position of a land affect its inhabitants.

These changes of land relief, and of climate, breed other changes of very great importance to all forms of life. It is a matter of observation that, in minor details, structures of animals and plants may be modified in accordance with modifications in their surroundings. Changed habits, necessitated by changed conditions of existence, may bring about the disuse of some parts of the organism, and an increased use of others. It is the theory of believers in organic evolution, that by such changes, carried on through very long periods of time, certain specialised forms may become so unlike their ancestors as scarcely to resemble them at all: during the same time, however, the original type may persist unaltered, those forms of it which have altered having been naturally selected on account of their special aptitude for existence under changed conditions in a changed form. Once started on its course of variation, the aberrant form may continue to vary until it dies out altogether, or until there is little, if any, apparent connection between ancestor and existing type. This is part fact, part theory; it is, however, built up around so vast a number of circumstantial details, that it must be, if not the whole truth, at least a very large part of the truth. Even those who believe that germs carry their own inherent tendencies to alteration, readily admit the great influence of environment upon every kind of life.

One purpose of the pages which follow is to outline the ever-growing complexity of living things as the ages of the Earth roll by. The reader will be in a much better position to judge how far facts and theories coincide, so far as evolution is concerned, when he has concluded the narrative; till then, I beg of him to suspend his judgment.

It is singular to reflect that these changes in environment, so vital to all organised beings, depend upon the action of natural weapons like wind, rain, frost and so on; and that they, in their turn, could not operate to any purpose, were it not for the vertical movement of the Earth's crust which so greatly resembles air bubbles beneath a cloth. For it implies that Man—a mighty object, whether we regard him as a Mind, or merely as Matter, a mass of cells—owes his existence to the waving up and down of a bit of earth. A strange conclusion! Let us examine the premises upon which it is based.

CHAPTER II.

The Birth of the Earth, and the Dawn of Life.

Of the origin of our planet we know almost nothing. It took place long prior to the earliest events that are recorded in the Stone Book, and its records have been destroyed. But, by analogy, many ingenious theories have been built up to explain the first beginnings of the Earth; and thousands of quarto pages have been filled with elaborate and brain-racking calculations in proof of assumptions which are *primâ facie* unprovable.

Early Speculations on the World's Origin.

The earliest known speculations in regard to the Earth's origin hail from the East, being incorporated in the Brahman religion. They, as well as early Egyptian and Greek legends, intimately mixed up the state of the world with that of human beings. It was universally assumed that there was a Creator, or First Cause, or God, and that apart from the Creator nothing originally existed. Out of nothing, the world and its inhabitants were made. There was no idea of any progressive development from low to high forms of life; and men were apparently always inhabitants of the globe. Human wickedness periodically grew to such dimensions that the Creator had to punish mankind by periodically destroying the world; its reconstruction and destruction in this way may have gone on indefinitely.

First Scientific Ideas.

The first true glimmerings of a synthetic history of the Earth are to be found in the works of Pythagoras, the philosopher, who clearly recognised that matter was not destroyed but only altered, and who observed many of the changes caused by the tools of nature, without, however, perceiving to what an extent these changes, if continued, might vary the face of the globe. The next advance was due to Strabo, the geographer, who explained the puzzle of marine shells being found at high altitudes as due to changes in the level of the land. But the human mind, in the aggregate, progresses slowly; and sparks of genius from one keen brain have frequently been lost for centuries. Through all the long period of the Roman Empire, this branch of science made very little progress. Fossils, the keys of the world's history book, passed unrecognised, except as mineral curiosities: where their reality was admitted, it was ascribed by Christians to the Deluge, and by unbelievers to the Black Art. It was not till 1517 that one Fracastoro arose, who pointed out the real nature and significance of fossil remains; and even his teaching was allowed to linger in obscurity for a couple of centuries more. In the last quarter of the eighteenth century, Pallas, Saussure and Werner made noteworthy attempts to split up the rocks into natural systems; but the last-named, a very clever German, so mixed up his facts with unjustifiable theories, that he may be said to have retarded geology quite as much as he advanced it. In the last years of that century, two eminent Englishmen, Hutton and Playfair, made the first real progress in the science (32). A little later, the illustrious French naturalist, Cuvier, declared that certain fossil bones were those of extinct animals, and so laid the foundation of palæontology. Meantime, one of those things had been happening which are so characteristically British. One William Smith, a surveyor and engineer, had occasion in the course of his duties to travel much about the country. He observed the relations of the rocks to each other, and was the first man who used fossils as a means of identifying rocks of the same age in different places. Extending his observations bit by bit, he mapped the whole country geologically, without the aid of a soul; his original observations were distributed to interested people *in manuscript*; and it was not until Waterloo year that his map was published. This man is justly known as the Father of English geology. Shortly after him came an illustrious trio, Murchison, Sedgwick and Lyell; to the latter is due the credit of popularising geology, and of explaining away ignorance and overcoming prejudice. Thus, the science proper is scarcely a century old.

ASTRONOMICAL INVESTIGATIONS.

But the problem of the Earth had meantime been attacked from other sides. The patient astronomer, sitting night after night in the cold, with his primitive spy-glass turned upon the starry wilderness above, had found strange thoughts arise in his mind, as he pondered over the secrets of those inextinguishable lamps of heaven. Up to the end of the fifteenth century, monasticism had been all-powerful in the intellectual world, and the science of optics was in a very primitive state; since nothing was permitted by the monks to be even argued about, which did not redound to the glory of God and the Pope. But at last one bold man, Copernicus, throwing off the chains of blind bigotry and prejudice, dared to assert that the solid Earth, so immovable to our unaided senses, was but a small ball, circling in space around the Sun; and though he and his disciples went in peril of their lives, the new doctrine steadily gained ground, until the main outlines of the solar system, as now known, were defined: Galileo, Kepler and Newton were the three most illustrious men who advanced these principles. Slowly and haltingly, knowledge has grown on their sure foundations, until to-day it is an edifice so great that one who enters can never be certain where he will emerge. Such a statement as that the whole solar system is travelling across the universe at some 400 miles a minute, excites no comment in these days of world-wide education: four centuries ago, the man who made it would have been burned at the stake.

THE VALUE OF A SPECTRUM.

Now, everybody knows that white light, if passed through a glass prism, gives all the colours of the rainbow. If the aperture through which the light is directed upon the prism be reduced to a suitable slit, the colours can be made to show in the true order of a rainbow, and not as a confused mass of colours: this ribbon is called a *spectrum*. In the early part of last century, a man of genius discovered that the spectrum of sunlight was marked by a number of fine black vertical lines, over 600 of which he counted; these were called, after him, Fraunhofer lines, but for many years their nature was a mystery. Then another observer, Kirchhoff, discovered that gases in a state of combustion have each a special colour, and that when these gases are burned in front of a glowing solid body, their light is absorbed by it—*i.e.* blotted out, leaving only the black spaces of the Fraunhofer lines. The position of these lines being invariable for each gas, a key had thus been cut whereby man could tell, analogically, whether any elements known to him were present in sunlight or in the light of the stars. For example, sodium, when ignited gives a yellow flame. There is a similar flame in the Sun's spectrum, in the true position that the sodium flame should occupy: therefore, by analogy, sodium is being burned in vast quantities in the Sun, or in other words is a constituent part of the Sun's fiery mass. The application of this important discovery to astronomy, especially by Sir William Huggins, has shown the significant fact that the sun and stars contain among their elements, in addition to gases unknown to man, others which are very common on the Earth: two of the most important, in the Sun, being hydrogen and calcium.

These facts have furnished data for many speculations, which are, on the whole, more related to astronomy than to our present purposes. Furthermore, the constant and increasing use of photography for star observations, and the recent improvements in mechanical optics, have given to the study of worlds in general an enormous impetus; and the result of all this has been to add greatly to the value of those hypotheses concerning our own small world's origin which we shall immediately consider.

Primeval Matter.

As to the origin of matter, we are not here concerned with it. We must confine ourselves to the simple assertion, that before the Earth had any existence, matter did exist in one form or another, and that out of that matter the Earth was created. We can localise this matter, to the extent of saying that it probably once included the planets, which, together with the Earth, revolve around the Sun; for the reason that there are so many interrelations between these various bodies as to render it highly probable that they had a common origin. The Sun is but a single star, and that not of any great size. It occupies what human beings call the universe, in company with many millions of other stars, from which it is separated by distances so vast that, although we can write them down in figures, our senses are lost at them. The planets, or "wanderers," as the Greeks called them, are relatively close to the Sun; dependent upon it, and, in a sense, inseparable from it. The Earth, huge though it may seem to the storm-tossed mariner in a tiny schooner, is but one-millionth part of the size of the Sun; its motions, its seasons, its plants and animals, all depend directly upon that luminary.

Laplace's famous Nebular Hypothesis.

What was by far the most popular theory of the Earth's origin for many years, was based upon this unity of the Solar System. This is the celebrated Nebular Hypothesis, which was propounded by Kant, a German philosopher, and expounded by Laplace, a French mathematician, nearly a century and a half ago. It assumes that the Earth and the Moon, the other planets and their moons, all of which now revolve about the Sun much as points upon the spokes of a wheel, had a common origin with that luminary, in a whirling mass of incandescent gas, or a nebula, spinning round like a ball in space. This gaseous mass must have had an extraordinary chemical composition, since it necessarily included all the elements now found on the globe, together with all the others in the whole system. Outside the nebula was something known as the Ether of Space—a very mysterious thing, beloved of philosophers; and the friction of this ether retarded the motion of the nebula, the outer portion of which consequently became both cooler and denser than the rest. Meantime, gradual condensation at the centre made the interior masses of gas whirl faster; the outer portion, lagging behind, was finally torn off, and left in space as a ring. The ring, obeying the laws of centrifugal force, broke up by coiling along its inner margin into a globular mass; and thus the first planet, the recently-discovered body outside Neptune, was born. Throughout the time of these changes, it continued its motion around the hot and still enormously diffused residue of the nebula; while the same forces of cold and friction, setting to work on the latter, gave rise to planet after planet, in the same way as the first. From the planets, the moons were formed as microcosms of themselves. The whole system of planets and moons was retained rigidly in position by the mutual attractions and counter-attractions of gravity: that mysterious word, which, almost daily, makes thinking men realise the narrow extent of their knowledge. The centre of the system, the axle whose intangible spokes hold everything in place, the shrunken remnant from which so many worlds have been created, is the Sun: a dwarfed and freckled shadow of a mass of light, the coruscations of which must have at one time been truly stupendous.

Objections and Alternatives to Laplace's Hypothesis.

This beautiful idea, a masterpiece of combined reasoning and imagination, accounts for many of the phenomena of the solar system, but not for all of them. Thus, the outermost moons of Jupiter, Saturn and Uranus, and the moon of Neptune, move in the reverse direction to all the other moons and all the planets; no explanation whatever is afforded of comets; and it is doubtful if the force of gravity is sufficient to retain such tenuous masses of gas in position. Then there exist, outside the Earth's orbit, and mainly between the planets Mars and Jupiter, a great number of small bodies called Asteroids or Planetoids, in size from 100 miles diameter upwards. The existence of these can only be accounted for, under this hypothesis, by assuming the disruption of some former planet: a convulsion of nature which is inconsistent with the history or physical condition of any of the planets. There should, also, according to the theory, have been a progressive cooling of the Earth since it was formed, and also a progressive decrease in the amount of heat received from the Sun; but yet, there has been no appreciable change in either during a period of perhaps fifty millions of years—surely too vast a time to consider negligible, even when dealing with celestial phenomena. There are various other objections, of a more technical nature, which have led to hypotheses that, though retaining the conception of a nebula, have given to it a different shape, and a different history; spiral nebulæ, of which there are many in the sky, have inspired some thinkers; while others believe in a pear-shaped nebula, the small end of the pear being the part cut off.

An important theory of a different nature postulates that the original solar system was not tenuous gas at all, but a molten fluid mass, forming a greatly swollen sun; and that disturbances caused by the passing too near of another sun set up tides in the mass, so that waves of particles were projected from the latter into space, where they slowly aggregated into the planets as we now know them. This theory, also, is open to very grave objections; although space is undoubtedly occupied by immense swarms of dark particles, which are visible as the clouds and blotches in such starry masses as the Milky Way.

One objection to the nebular hypotheses is that the shape of the Earth is not what it should be—to wit, a slightly flattened ball, or oblate spheroid. During many years, very exact measurements have been made over arcs of the Earth's surface, which prove some slight departure from this strict form. Scientists have even argued, out of totally inadequate data, that the shape of the Earth is tetrahedral; but it is to be doubted whether these conceptions, though brilliant and original, do much in reality to advance the cause of science. Nevertheless, if one turns aside from one or other of these hypotheses, there is exceedingly little to go upon. It must also be borne in mind that the earliest of them was put forward by Laplace, in the true spirit of science, as being merely a speculation. In the same spirit, let us follow out the consequences of his theory, as applied to our planet, and see whither they will lead us;

premising that, so far as Earth history is concerned, only the records of the rocks are of real value, and these are necessarily immensely younger.

CONSEQUENCES OF LAPLACE'S HYPOTHESIS.

We must, then, first conceive the Earth as a revolving ball of incandescent gas, which, long after it had thrown off the moon, still occupied a much larger area in space than it does now. Stellar space is believed to be intensely cold; and we can assume that its chilling influence caused a differentiation of the Earth-gases into more or less definite layers, of which steam and nitrogen would possibly be among the outermost: this outer steamy layer would be hundreds of miles thick, and its density, like that of the air, would be less the farther one got from its base. There may have been winds, of a violence almost inconceivable to us; and perhaps the steam, condensing, fell as rain, only to be vaporised again as it reached a hotter layer; while the nitrogen concentrated, mixing with some of the oxygen to form air. These processes would continue for an indefinitely long period; until, in short, the combined influences of stellar cold, a definite atmosphere, cooling rain, and radiation of heat from the Earth's interior, made the layers immediately beneath the steam cool enough for a crust or scum of solid rock to form upon the glowing globe. Although forming with extreme slowness, this crust would probably not have the minutely crystalline texture which is to be observed in granite, but would be slaggy.

THE EARLY EARTH.

All that is certain (and it is absolutely certain, in any rational explanation of the Earth's origin) is that eventually there *was* a crust or surface of solid rock. After its formation, the atmosphere must have grown sensibly cooler. Thus the rain and stream water would collect in every hollow upon the surface, until there came into existence a primeval ocean. There is good ground for believing that this ocean was of fresh water, in that it contained little or no common salt; but in many respects it was, in all likelihood, a hot and evil-tasting liquid.

At this stage in its evolution, the planet must have very nearly approached to the popular conception of Hades. On account of the thinness of the crust, volcanic explosions and lava flows would be of almost daily occurrence, and exhibited on the grandest scale. There was no cold, no sweetness in the waters. The winds would be mere hot blasts, as from a furnace top. The atmospheric conditions were such that life, under any form known to man, could not possibly have existed.

But in the course of ages, continual radiation of heat into space gradually cooled the Earth, its seas and its air; while the thickening crust made possible longer and longer intervals between the volcanic outbursts. Nevertheless, it was still exceedingly desolate: a mass of rusty, iron-stained rocks; of black, barren lava slopes, corded and knotted into a thousand fantastic forms; of deserts and dust storms; of dark, brooding waters, untenanted by even a weed. Long after this cooling down, nasty little pockets of poisonous gases would continue to lurk in favourable localities, just as gas lay in shell holes during the late war; but gradually these foul vapours were dissipated into space.

To this point in our inquiry, every other hypothesis of the Earth's origin must eventually bring us. Before proceeding, therefore, it will be as well to glance at the principal alternative theory to that of Laplace.

Planetismal Hypothesis.

It is mainly the work of an eminent American scientist, Professor T. C. Chamberlin; and is the opposite of the nebular hypothesis in all respects. Space is known to be occupied by great numbers of meteorites, or, as they are popularly known, thunderbolts or shooting stars; and in passing, it may be remarked that these stones, varying in size from a pebble to a mass weighing 85 tons, have been repeatedly found upon the Earth's surface. He assumes that the planet was built up, during a long series of ages, by the agglomeration of a vast number of small meteorites, each of which carried (as all rocks do) a certain amount both of air and water. At first, a few formed a core; and around this core the others were successively grouped. We can easily conceive the process, by imagining the budding globe to be a currant dumpling, on the outside of which we are for ever sticking bread crumbs. The pressure caused on the inner constituents by the accumulation of so many meteorites generated great heat in the mass, and the contained gases were consequently expelled, accumulating upon the surface, one series as water, the other as air. This theory, highly ingenious though it is, lacks the fascinating simplicity and completeness of that of Laplace; but it has numerous points in its favour in the starry vault. All that concerns us now, is to note that it brings to us a world with a rocky surface, an ocean, and an atmosphere.

THE PAST WAS SIMILAR TO THE PRESENT.

The tendency of most geologists is, and has long been, to believe that the present is the key to the past; for geographers the past is the key to the present. Though the origin of our lands and seas must be looked for far back in remote ages, millions of years ago, the deposits which were formed in those ages (which are analogous in every respect to those forming or capable of being formed to-day) were the work of precisely the same forces as operate at present; in other words, rain, wind, cold and the ocean, shaped the land of those far-off days just as effectively as they do our modern continents or islands. Therefore, once we get the planet out of the labyrinths of hypothesis, into a globe with a solid surface, an atmosphere and an ocean, all its subsequent history becomes a matter of certainty; although the details of that history may be now and then obscured, or even obliterated. Of the order in which successive events transpired, also, in times prior to the records of the rocks, we must necessarily always be ignorant. At some time or another, all the varied phenomena of seasons began to have effect; but the temperature all over the globe was very hot and very uniform. The first waves rolled sullenly along the first rocky shores; the first rivers started picking up salts and sediment from the land, and dumping them into the ocean; the tides, beginning that titanic labour which they have never intermitted for a moment since, applied a kind of brake or drag upon the Earth's rate of rotation. When the sea had cooled down to about 180° Fahr., it is possible that the great marvel of marvels in human eyes took place, and Life began (33).

Origin of Life.

How and when this vital event actually occurred, no one knows. Being but human, we can only think within the limits of our own narrow experience and our own feeble knowledge; and it is sometimes difficult to express even that modicum of knowledge and experience in words. But all that we do know teaches us to conceive that, just as the Earth certainly had a beginning, so all things upon the Earth, Life included, also had a beginning. It is when we come to the question, "What from?" that we commence to tread upon thorny ground. There are three main ways of viewing the question. People of strong religious convictions have not the slightest doubt that Life is due to a dispensation of the Almighty, the Creator of all things, God, or the Unseen Force of philosophers—all names expressive of the same idea. At the other end of the scale, the pure Agnostic believes in nothing which is not demonstrable; and as the origin of life is not demonstrable, he evades the question. In between these two extremes are the doubters—those who cannot conceive that the Universe came from nothing, and therefore admit the existence of an Almighty; but who seek to explain everything upon the Earth and in the heavens, as far as possible, by analogy from the results of human experience. These last, in my humble opinion, are treading more closely in the straight and narrow path of truth than the others. In their ranks are a number of eminent and earnest men who are convinced that Life had an inorganic origin; that is to say, that living matter was originally created from matter which never had been alive.

There is a great deal to be said for this belief. It must never be forgotten that, in all our physical speculations of this nature, we are very largely playing with *words*. For instance, what is meant by Life? Is it matter which has the power of motion? If so, then all matter is living, for it all responds to the influence of heat and cold, by expansion and contraction. Is it matter which has the power of growing and reproducing its kind? Then crystals must be living, for they grow, just like animals, to a certain size and no more; and the matter out of which they are formed reproduces their like with marvellous fidelity. Is it matter which has the power of assimilating other matter? But that is a chemical function of many inorganic bodies. Thus, if taken back to the first beginnings, it is very difficult to say where living matter begins and inorganic matter ends. The relations between the two great kinds of Life, animal and vegetable, are just as obscure; for there are a goodly number of minute bodies, one-celled in structure, which no one can positively say are either animals or plants. These are the simplest particles of living matter known to exist. Such one-celled organisms may comprise either a body of a definite shape, or a little jelly-like blob.

which crawls about by the extension of any part of its surface, and which assimilates inorganic particles as food, by similarly pushing out lobes of its body and encircling them. Many of these tiny bodies, which are composed of a substance called Protoplasm, present, under a high-power microscope, a granular structure, sometimes with a fine network encircling it; and in some part of the body there is usually a darker spot, known as the nucleus: this is intimately connected with the process of reproduction. Professor Schafer has suggested that these nuclei were the original forms of life (34), and has advanced much in favour of his contention. The argument carries us back to one or more places, in which the few elements that compose nuclear matter chanced to be associated; and this may have given rise to the original forms of life. That is to say, life may be the result of a chemical combination which was brought about by accident.

But even if such a beginning for living matter be granted as being well within the bounds of possibility, the reason for the inherent tendency of matter to vary and the development of consciousness bring on at once a vital question; and that leads to a crowd of others, which it is certainly not appropriate to discuss here. All we propose to say, therefore, is that life did begin on the Earth; that it did vary; that out of its variations the first few primeval natural kingdoms were evolved; and that out of these last, by stages which will be illustrated during the progress of this book, the modern forms of life slowly grew. The idea that life came to the Earth from some other planet, hardly deserves serious consideration; for it only removes the difficulty a stage farther back. As to religious objections, more has been written about them than they deserve. The Universe and all its parts redound to the glory of God, no matter under what form we worship Him.

THE EARLIEST FORMS OF LIFE.

Probably, simple forms of algæ and bacteria, the most lowly of plants, were the first organised beings to have an existence; certainly one, and probably both, originally dwelt in sheltered parts of the sea. Where, in that dim past, the continents and islands lay, under whose lee this life developed, we have not the remotest inkling, nor can we ever hope to learn; for it is very probable that the rocks of those days have been fused by subterranean heat and totally destroyed. Nor, again, can we say how great a gap there was between those primeval lands and the deposition of the rocks which I shall presently describe. There may have been continents which were worn down to ocean level, time and time again, before the geological record begins. We do not know. Because of the Earth's internal heat, all these things are lost for ever.

THE OLDEST ROCKS ARE CRYSTALLINE.

Now, the sources of most of the relatively modern rocks, such as sandstones, conglomerates or puddingstones, shales or limestones, can generally be ascertained by carefully noting their mutual relationships, and by deductions based on differences in the size of grains or pebbles—the largest, as a rule, being those nearest the source, and a gradual increase in fineness denoting a corresponding increase in the distance from the point of origin. But deductive methods of this sort fail us, when we examine the oldest rocks of which there is any trace. For these rocks are almost invariably crystalline, and have their original texture more or less obliterated. Microscopic analysis is a great aid in detecting their nature, but it rarely helps us to discover their immediate sources. These rocks are, besides, so poorly exposed to observation, so folded and fractured, and so similar to one another in different parts of the world, that only with extreme difficulty can any connected account be given of their history, even for limited areas and in a general way.

Here we find an apparent anomaly, on the very first page of the Stone Book. The oldest rocks known are not the lowest rocks seen. They rest universally, so far as known, on masses of granite, which send great tongues and fingers into them, and so prove beyond dispute their relative ages: how much younger the granites may be depends upon many circumstances, but they are often many millions of years younger. I explained in the last chapter that there is a zone in the Earth's crust, at no great depth, where, owing to the heat, all rocks must be in a state of fusion: it is such fused masses which form granites as soon as they are cooled sufficiently for their component minerals to crystallise under pressure; and this molten matter or magma, at some time or other in the remote past, laved the under surface of the oldest rocks on the globe.

In the main, the oldest existing rocks are themselves of igneous origin—that is to say, they were derived from the Earth's interior, either as lava flows, masses of pumice or intrusive dykes and veins. This is shown by microscopically examining thin slices; when the minerals present will be found to be those characteristic of more recent lavas, granites, etc., and totally unlike those which typify rocks derived from denudation.

THE ANCIENT ROCKS OF SCOTLAND: LEWISIAN GNEISS.

These ancient rocks, which, as a whole, are generally called *Archæan*, or *Pre-Cambrian*, occupy a very considerable part of Scotland, forming the whole of its north-western coast. They have been so greatly compressed, fractured and altered by subsequent earth movements, that the constant labours of half a century have not fully unravelled their tangled story;

but so far as it has been made out, it is as follows. Upon a sea floor, the nature of which is not known (no trace of it having been found), great masses of lava, now changed to greenstone, were poured out, in part from fissures and in part from true volcanoes. Later, other masses from the same molten reservoirs pressed up through cracks in the first, cutting across or intruding them, in the form of dykes or sills, often of considerable magnitude. A few of the volcanoes rose above the level of this ancient sea; from these were discharged, at irregular intervals, clouds of ashes. The volcanic period was a long one. From unknown lands in the vicinity, sand and mud were drifted into the marine waters, there to slowly accumulate in horizontal layers. In a few places, particularly near the sites of Loch Tay and Loch Maree, the sea was sufficiently deep and clear to enable limestone to form on top of the lava beds. It is possible that seaweeds floated about, and there may also have been present much surface-water life, of a simple, jelly-like character, whose decomposed remains caused the precipitation of the limestone; but if this life really existed, none of its remains have been preserved to us.

Formation of a Mountainous Country.

Meantime, vertical earth movements were as much at work then as they are to-day. The area sank steadily beneath its accumulating load of lava beds and mud, until a great but unknown thickness had been deposited. Then came a pause. The solid rocks, reduced to a plastic state by the great depth to which they were buried and the extreme pressures they had to sustain, were bent and squeezed into all manner of fantastic curves and shapes; so much so that one can count angles by the dozen in a single hand specimen. As a result of this folding, the rocks were elevated above sea-level. Granite fingers pressed up against their under surfaces; granite hands raised them high in the air, compressing and altering them still further. Thus was created a mountainous area of a magnitude far surpassing anything that exists in this region to-day. It not only covered the Highlands of Scotland and the Hebrides, but extended across the site of the North Sea and involved a large part of Scandinavia as well (Plate 19). Far to the east, over Finland, the shores of this land seem to have terminated in a featureless ocean; in which, as formerly about the sites of the Scottish lochs, life of a primitive kind may have existed.

Slowness of the Elevation.

It must be understood that, although it is easy to speak of depression, elevation and mountain building in a single sentence, the actual operations occupied an infinitely long period of time. There is no reason why such changes should have been any more violent or sudden then than they are to-day; and we can safely apply the same rates of movement as have been observed in historic times. Remembering, then, that the land probably sank or rose only a few feet each century, it becomes apparent that Nature worked out her plan for creating the British Isles with an utter disregard of time or circumstance. The land probably emerged from the sea as a low dome, sloping gently down to the water on all sides; and while it rose, rain fell upon the almost flat surface, and shallow valleys were gradually carved out by its runnels. As time wore on, and the land rose more and more, fractures and cracks developed. All the agents of destruction, working in unison, succeeded in carving large parts out into hill and dale; until, at last, the combined result of uplift, denudation and faulting was a mountainous topography. If we picture to ourselves these various activities, remembering how slowly each of them

Pl. 16. Cliff of Torridon Sandstone, N.W. Scottish Highlands (p. 54). *D* 52.

Pl. 17. *E* 53.

Asama-Yama, 8315 ft., a Japanese Volcano.

The layered structure is beautifully shown here (p. 29).

operates, we begin to realise how vast a thing time is, how utterly insignificant we are beside it.

The above ancient rocks are known as the Lewisian Gneiss, from the Island of Lewis, where they are typically exhibited. They are, and have long been, singularly barren and desolate, giving rise to a type of scenery which, for wildness and loneliness, has scarcely a parallel in the world. Their colour is very generally a sombre, heart-breaking grey. Being excessively hard, and so almost soilless, they are useless to the agriculturalist, and the despair of the engineer. The cotters and fishermen who eke out a precarious livelihood on the margin of this area have, indeed, to earn their bread by the sweat of their brows.

Names of Crystalline Rocks.

Gneiss, I may remark in passing, is a German word, which covers numerous crystalline rocks, whose commonest character is for the minerals of one kind to collect into a band, the different minerals thus giving the rock a ribboned appearance. Before the application of the microscope to thin sections of rocks, it was long imagined that, because of the separation of the minerals in this way, these rocks were sediments, each band being a bed laid down in water; but the appearance is really due to pressure being applied to the rocks, compressing and breaking down the original minerals, separating them into layers, and forming new minerals, such as mica, out of their fragments. All such altered rocks are called *metamorphic*, which merely means *changed*. When the altered rock is foliated, it is called a schist. Names are prefixed to these two terms, gneiss and schist, to denote the nature of the prevailing minerals: hence the expressions, granite-gneiss, muscovite-biotite-gneiss, chlorite-schist, sericite-schist, etc. I hope to avoid using most of these formidable expressions, however; they are in our language, but not of it.

Torridonia in the Making.

When the old Lewisian land surface had reached such a stage that it had hills which rose steeply to a height of at least 2,000 feet above the valleys they overshadowed, a relatively rapid accumulation of matter buried them again. At this time, the situation of the land, as regards altitude, was very much as it is now; the great thicknesses of rock which subsequently covered it having protected it against the ravages of an immense period of time. Parts of it which have been but recently exposed, by the wearing away of their surface cover, now form the oldest land surface in Europe (35), and one of the oldest in the world. The tourist, wandering in those regions on his summer holiday, thus has the unsuspected privilege of standing on a surface which was land many millions of years before the Alps or the Himalaya had their origin.

The overwhelming of the ancient land was so clearly done that one can perceive, in places, traces of where the fragments fell from the cliffs and lodged in the mud or sand upon the shore; the waves not having time or force enough to round them into shingle, ere they were buried beneath a fresh accumulation (36) (Plate 18, A). The accumulation of débris, which was widespread, involved Scandinavia as well; and it resulted in the formation, layer above layer, of an enormously thick and very curious body of red sandstone, of which the striking remains now to be seen in the precipices of Scotland and Norway are but the most meagre fragments. This rock, from its splendid exposure on the shores of Loch Torridon, is known as the Torridon Sandstone (Plate 16).

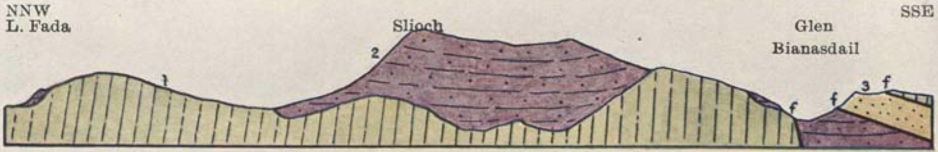
The Torridon Sandstone is excessively hard and resistant to weathering; and is, in consequence, the landscape architect in most places where it occurs. It forms wild peaks and cliffs, well-nigh unscalable; deep red in colour, and crowned, in numerous cases, by candlesnuffer-shaped masses of a whitish quartz rock, they give a singular beauty to the Highland wildernesses.

The mode of origin of this sandstone is in doubt. It was certainly laid down mainly in shallow water, subject to violent currents. It was doubtfully marine; but its red colour and angular nature suggest that more probably it accumulated in desert valleys, as the result of torrential storms or cloudbursts. Its nature indicates that a cold, arid climate prevailed. But the most remarkable thing about it is that many of its rocks were not derived from the Lewisian land at all, but from other lands, partly volcanic, which are now completely hidden from observation (37). Despite its great antiquity it is very little changed. Its thickness is enormous, amounting to at least 16,000 feet, and possibly as much as 19,700 feet (38); and in all this huge mass no fossil remains have ever been found, except some doubtful sponge spicules. It seems probable that the iron with which the rocks are heavily charged, and which is very destructive to fossils, has removed all traces of such remains as there were. It is also probable that most of the organisms were of a soft-bodied character, and were almost confined to the open sea.

Elevation of Torridonia.

At length the movement of depression, which the vast thickness of the Torridon Sandstone implies, ceased. The inevitable reaction raised all the rocks high in the air, giving them a gentle tilt to the east; and it seems likely that in that direction, after due time had been allowed for the sculpturing of the land, broad rivers flowed over gentle plains to a shore which ran across the Russian border of Finland: flowed so long and so quietly that the summits of the hills decayed away into deep soils, and the land was furrowed and worn like the skin of an old man. But it must not be imagined that this land was in any sense beautiful. There were no meadows, no forests, no swamps even; no quadrupeds grazed there, no birds flew there, nothing crawled upon the soil. Apart from possibly harbouring a few larval forms of crustaceans and molluscs in the estuaries, and a few weeds and filmy masses of green scum in the quieter stretches of its streams, it was wholly devoid of living things.

The late elevation was marked by a total absence of the crumpling, volcanic activity, and upward movement of molten granite which distinguished its predecessor. It was probably so slow, so insensible and evenly distributed, that had we lived in those times we should not have known, even by combining together the observations of centuries, that anything untoward was going on. But from the moment when the first bare patch of muddy sandstone showed above the waters, to that when, ages later, the last proud hill silently disappeared once more beneath the sea, all the natural agents of destruction were at work like fiends upon it: grinding it away, grain by grain and inch by inch, until in places the entire thickness of the sandstone was removed, and the old gneiss laid bare once more. One is thus driven to conclude that the land of Torridonia may have been several thousand feet above the sea, and a sharp relief imprinted on its surface. Part of the sediment which was removed during all this time, now lies hidden from view beneath the deep Atlantic; part was deposited in a sea to the south and south-west. The gradual creeping northwards of this sea inaugurated a new and very different epoch, the *Cambrian*, which will be referred to hereafter.

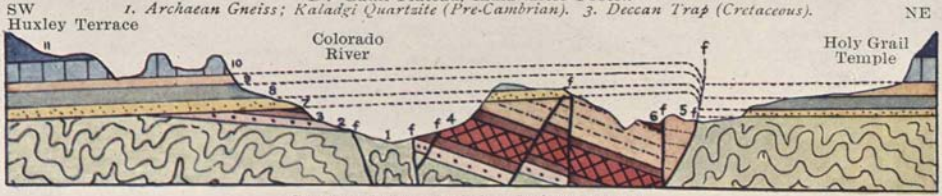


A North-West Scottish Highlands (after Peach).

1. Lewisian Gneiss. 2. Torridon Sandstone. 3. Cambrian.

B: Gauli Plateau, India (after Foote).

1. Archaean Gneiss; Kaladgi Quartzite (Pre-Cambrian). 3. Deccan Trap (Cretaceous).



C: Grand Canyon, Colorado (after Noble)

1. Archaean. 2-6. later Pre-Cambrian. 7-9. Cambrian. 10, 11. Carboniferous. f.f. Faults.

Pl. 18. *E* 56

Sections through Pre-Cambrian Rocks.

Pl. 19. *E* 57.

Pre-Cambrian Topography, Norwegian Plateau (p. 52).

Photo. Wilsse.

WHAT ROCK THICKNESSES IMPLY.

Let us pause here for a few moments, just to consider the thicknesses of rocks, and what they mean in terms of years.

All sedimentary rocks are laid down in beds, one above another, at angles very little, if at all, removed from the horizontal. Each bed represents a certain event in the Earth's history; each series of beds of a like nature or containing similar organic remains makes up a formation; and a varying number of formations, which are more like each other in their nature and organic remains than the formations above and below them, constitute one of the major divisions of geological time, and are referred to herein as an "Age." There are sixteen Ages in all (Plate 21), most of which comprise a thickness of 20,000 feet or more of rocks; thus, the whole geological chronology comprises up to 130 miles' thickness: an amount so great that we should never be able to examine it, were it not for the circumstance that rocks are tilted up, so that their thickness, instead of being measured vertically, must be computed at various angles down to horizontal. Besides being bent at times into large curves or sharp contortions, most rocks are more or less faulted; that is, earth-stresses have developed fractures in them, along which one side has slipped down, or the other been thrust up, or both. In the more ancient rock groups, and even in some of the recent ones, continual slips along these fault lines have moved the two parts of a bed thousands of feet apart; so that one may stand, literally, with one foot on deposits immeasurably younger than those on which the other foot rests. This circumstance, coupled with the unequal denudation which the rocks have undergone, makes it exceedingly difficult, as a rule, to get the whole of any one formation into the limits of a single view; and as, by a conspiracy of nature in hiding rocks with vegetation, even a good view of *part* of the formation is more often desirable than attainable, the labour of measuring thicknesses becomes a heavy one. Nevertheless, by tracing conspicuous beds from place to place, and measuring upwards and downwards therefrom, very accurate sections can be made; and it is in this way that 16,000 feet has been arrived at for the Torridon Sandstone. The top of the formation having been removed by denudation, this thickness must once have been more; how much so, it is impossible to say.

Average Rate at which Rocks are laid down.

Now, Professor W. J. Sollas, in a well-known study of the age of the Earth, estimated that, after making due allowance for variable factors, the *average* rate at which sediments are laid down beneath the sea is one foot per century (39): that is to say, if all the waste of any kind derived by wind, weather and water from a land during one hundred years were deposited uniformly over the neighbouring sea bottom, it would be one foot thick. There are some serious technical objections to Professor Sollas's calculation; but if we remember that it is only a rough average, and that there is, as yet, no real mode of measuring past time except between wide limits, it will serve to give us a fair idea of the duration of the Ages. For instance, it tells us that the Torridon Sandstone must have been accumulating for nearly 1¾ millions of years; and during the whole of that time the Earth's crust, from Scotland to Norway, was slowly caving in, though at different rates in different places. Then after deposition ceased, the great mass had to be raised again at least 10,000 feet, and possibly much more; which, if we assume a rate of movement similar to that observed at the present time in Sweden—3 feet per century—would occupy 300,000 years. These figures take a good deal of realising; but time, as I remarked before, is relative, and we only look at it from a human point of view.

Consider how large a window pane must seem to the fly that buzzes on its polished surface!

Gradual Wearing away of Torridonia.

Of course, throughout the quarter of a million years or so that the Torridon land spent in attaining its maximum height above sea-level, it was, in detail, being carried back to its watery bed again. Yet that it remained, as a whole, above the surface for an infinitely longer time is evidenced by this fact: when the re-submergence in Cambrian times came, the whole of the rocks—Lewisian gneiss, granite bosses, ancient limestones and Torridon Sandstone—had in places all been neatly bevelled off into the semblance of a plain; and we must remember in this regard that the lower the relief became, the longer did it take to remove a given amount of the surface. The denudation which has worn the sandstone into the mural precipices that are now its most characteristic feature, was the work of a much later age.

England and Wales in this Age.

If, turning from Scotland, we glance at the condition of England and Wales in those remote epochs, we find only isolated remnants of the pre-Cambrian rocks, rising like islands out of a sea of younger land. Such are the Malvern Hills, a few patches in the extreme south-west of Wales, parts of Charnwood Forest, part of Shropshire and most of Anglesey. They tell us very little; their scarred old faces are as inscrutable as that of the Sphinx. But it is known that at a fairly late stage there were one or two small volcanoes near Milford Haven (40); and that the lands to the north, in Wales and on the Irish shore, had been so long above the surface that their rocks, crystalline in texture, had crumbled away into dust.

Elsewhere in Europe, particularly in the heart of France, in

Spain, Bavaria, Bohemia and Finland, rocks of this age are to be found. They bear evidence of two distinct periods, one corresponding to Lewisian Gneiss times and the other to late pre-Cambrian times; but they are so very old, so very dry, crumpled and withered, that we shall do well to leave them in their self-imposed obscurity.

Pre-Cambrian Life probably Soft-Bodied.

In none of these rocks have any indisputable fossil remains been found. This almost universal barrenness indicates either that there was no life, or that it was so soft-bodied as to be incapable of preservation; otherwise it would certainly have been discovered during the patient researches of nearly a century, in some of the less highly altered rocks. That there was life we may be absolutely certain. For in the next age, the Cambrian, we find a wonderful assemblage of Protozoans, Sponges, Jellyfish, Marine Worms, Sea Cucumbers, Seaweeds, shell-forming Molluscs and many different kinds of Crustaceans. These certainly did not come into existence in a moment. They have been studied with extreme care and minuteness, and their points of relationship with modern forms determined; and nothing is more certain than that each of the above natural orders had a long ancestry, carrying it far back into the pre-Cambrian ages. It is regarded as probable that the primitive ancestors of the Cambrian fossils descended from one another, until, by going back far enough, one would find only simple, one-celled algæ, protozoans and bacteria; but although some marvellous things have occurred in the way of preserving soft-bodied organisms, it is too much to hope that the veil of mystery will ever be, in any material degree, lifted from the beginnings of life, as written in rocks. Singularly enough, however, bacteria, the most minute and difficult objects to find under the microscope in a living state, appear to have been clearly determined in very ancient pre-Cambrian rocks in North America; chains of minute cells similar, superficially, to the modern Micrococcus (41), one form of which is the cause of mammitis in sheep, and another of gonorrhœa (Plate 20, 2). This is a wonderful fact. A man may die, and his bones rot away into dust, and the dust be blown into the ocean and dispersed for ever; yet the tiny parasite which feeds upon him may be preserved, many millions of years, through countless changes of all sorts, practically unaltered: so great is the little, and so little the great!

Great Development of Archæan in Canada.

Continuing our survey of the Archæan world, we come to Canada, where there is the largest area of these rocks on the globe—a space almost as large as Europe. They form the jagged and forbidding coast of Labrador. Their reds, greys, greens and browns extend as far west as the border of the Mackenzie River basin (42), and as far north as the tundra-covered Arctic shore. Their hardness is part cause of the innumerable lakes and waterfalls which dot the Dominion. Their lack of soil forbids vast areas from ever becoming useful agriculturally. But they have, for many minds, infinitely more interest than the fairest landscape could bestow; for they contain all that creates man's cupidity and excites his energy—gold, silver, copper, nickel and many other less precious metals. The magic radium is there, though not in great abundance, even for radium (43). Innumerable miners have ruined their lives in grim battle with the secrets of these ancient rocks; a favoured few have wrested fortunes out of them with almost ridiculous ease.

The Laurentian Plateau as it is.

At the present day, these rocks form a great wilderness of an average elevation from 1,000 to 1,500 feet above the sea, smooth like a plateau when viewed from a distance, but extraordinarily rough when seen in detail. They were the birthplace of the vast ice sheets which overspread much of North America in the Ice Age, and the moraines left by the ice have added to the wildness of the topography. Innumerable lakes of every shape and pattern, with crystal-clear water, and banks clad by spruce or larch, fill all the hollows; innumerable winding streamlets, each with a series of picturesque rapids or more formidable falls, indicate how feeble the work of the water has been since the ice left the region. The immense forests that sprang up on the withdrawal of the ice have in many places been burned down, and their blackened stumps make up a picture of utter desolation: elsewhere, a second growth of vegetation forms impenetrable tangles. Many swamps mark the sites of former lakes. Many little clearings on the sand- and mud-filled basins of other former lakes show the slow, stern struggle of man to colonise the wilderness. In the waters are whitefish and sturgeon and trout; in the woods lurk bears and wolves. Man, the master of all this, is forced, in the main, to keep to the south, and to live in much-extended settlements along his railway lines. It is little wonder, then, that this mysterious expanse should have had a long and mysterious history.

THE OLDEST ROCKS KNOWN.

The oldest known rocks in Canada (perhaps in the world) occupy a very modest area north-west of Lake Superior, in the vicinity of Rainy Lake. When they were laid down, that region appears to have been a shallow sea, into which were washed, for a very long but unknown period, various kinds of sand and mud. Whence this matter was derived, and what rivers transported it—whether the land was high and rocky or low and flat—we do not know, and probably never shall. But it is a remarkable fact that, at the very commencement of geological time, we find in operation precisely the same processes which are at work now. These most old of old rocks are known as the Coutchiching Series (44).

IMMENSE VOLCANIC OUTBURST (KEEWATIN).

The next event in the history of the region is obscure; but probably the Coutchiching rocks were still under water when subterranean fires burst forth, with a violence and on a scale which has never been equalled since. The ejectamenta of volcanoes and fissures covered the country far and wide; and by far and wide, I mean from the plateau of Labrador to the foothills of the Rocky Mountains, and from the Barren Lands of the Arctic Circle to the natural parks of Wisconsin.

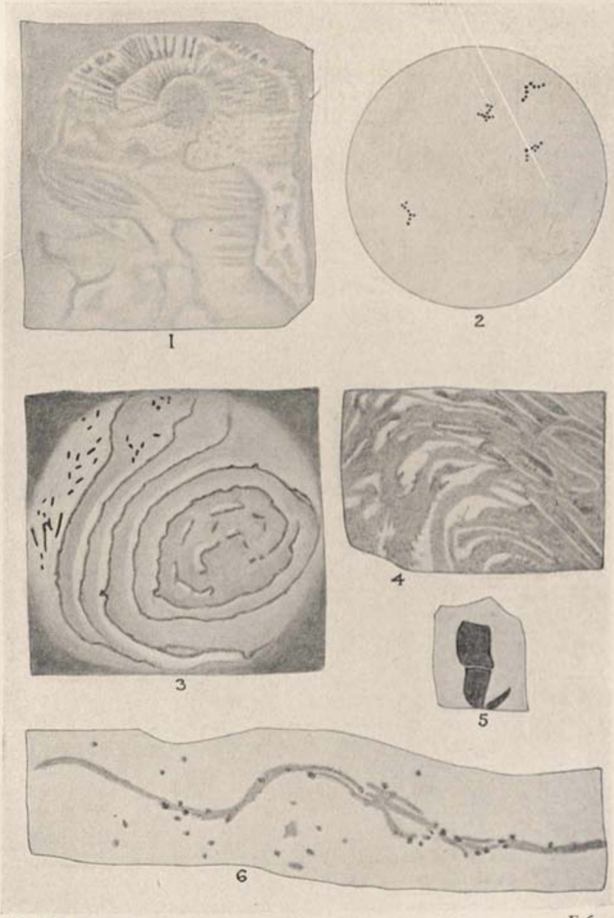
Lava, dust and ashes buried the country to an unknown depth. Far away in the south-west, also, the Grand Canyon region of the Colorado, and probably a large area extending right down to the border of Mexico, was the site of discoloured waters and bare, smoking, cinder-covered cones. It is certain that there were a number of islands in this sea, probably of volcanic origin; for their detritus, carried away by streams and assorted by marine currents, is sometimes found intermixed with the lava flows. It is also tolerably certain that the fiery deluge was preceded by earth movements on a vast scale, the records of which have been obliterated.

GREAT DURATION OF THE KEEWATIN.

It must not for a moment be imagined that the volcanoes were all rampant at the same *moment*, although they are of the same *period*. On the contrary, eruptions probably broke out first in one place and then in another, and there were regular lines of weakness along which lay chains of high, desolate black cones—in other words, what we see to-day in volcanic regions probably applied equally well then. Thus, there would have been, at times, long pauses—perhaps of hundreds of years —between successive outbursts of any one volcano; while another, resembling Etna, might burst forth furiously every five or six years. We can assume, too, that the whole cycle of vulcanism—which, beginning with earthquakes and eruptions, rises to a maximum, then passes through a spent and choking state, ending with the feeble efforts of boiling springs or geysers—was played out in one locality before the efforts of another began (Plate 22). As a concrete instance of the succession of events, there have been found recently, in two separate districts of Ontario, no less than fourteen lava flows piled one above another, to a total thickness of 4,400 feet in one case, and 7,300 feet in the other; and the upper surface of each flow had time to cool, and sometimes to be a little worn away, before the ejection of the next: this, moreover, is but a small part of the series (45). The Lava Age, which has been correlated, on insufficient grounds, with the Lewisian Gneiss, is known as the Keewatin; and in all that desert record, extending over the length and breadth of a continent, no traces of life have ever been found. Nor is it likely that any will be; for even the minerals have been so highly altered by subsequent earth movements, that their original nature is sometimes a matter of guesswork.

THE GRENVILLE SEA.

The lava flows died away. The exhausted Earth panted, and its surface heaved and sank. In place of the hot and turbid seas, which must literally have boiled as the streams of molten rock came into contact with them, a calm set in, as of a still morning over deep waters. Much limestone, mixed at first with volcanic mud, was formed. Gradually the sea grew



Pl. 20. *E* 64.

Pre-Cambrian Life. 1. Atikokania. 2. Micrococcus. 3. Cryptozoan. 4. Eozoon. 5. Beltina. 6. Annelid Trail. [4, after Dawson, others after Walcott].

NAME		MAXIMUM THICKNESS (FEET)				DURATION
Popular	Scientific	Britain	Europe	N. America	India	Millions of Years
Ages before Life	ARCHÆAN	Vast	but not	known		—
Dawn of Life	LATER PRE-CAMBRIAN	19,500	?	38,300	20,000	$4\frac{3}{4}$
Age of King Crabs	CAMBRIAN	12,000	10,200	22,500	4,000	$2\frac{3}{4}$
Ages of Mud	ORDOVICIAN	15,000	10,800	7,800	2,100	2
	SILURIAN	14,450	9,100	17,000		2
Age of Fish	DEVONIAN	20,000	18,900	11,000	3,000	$2\frac{1}{2}$
Coal Age	CARBONIFEROUS	22,800	48,500	25,900	4,000	6
Age of Deserts	PERMIAN	3,000	7,900	10,000	9,600	1
	TRIASSIC	5,750	8,500	10,000	10,000	1
Age of Reptiles	JURASSIC	4,300	4,000	9,000	8,000	1
Age of Chalk	CRETACEOUS	4,550	11,000	30,000	14,000	3
Age of Coin Fossils	EOCENE	1,800	3,300	20,500	3,000	2
Age of Lakes	OLIGOCENE	850	3,300	14,000	6,500	$1\frac{1}{2}$
Age of Mountains	MIOCENE	—	24,000	10,000	9,500	$2\frac{1}{2}$
	PLIOCENE	300	2,000	8,750	10,000	1
Ice Age	PLEISTOCENE	—	2,000	2,000	—	$0\frac{1}{2}$
Age of Man	HOLOCENE	—			—	—
	TOTAL	124,300	163,500	236,750	103,700	$33\frac{1}{2}$

Pl. 21. *E* 65.

Table of the Geological "Ages" (pp. x, 57).

Showing their approximate maximum thicknesses and estimated duration.

clearer and clearer, especially in what is now the heart of Canada, until at last very little earthy matter reached it, and for long ages it became a vast repository of limestone. The full story has not yet been worked out; but it seems that, while in the west of Ontario and east of Quebec there was either shallow muddy water or dry land, the area north of Lake Ontario, including the bulk of Labrador, became a wide, clear bay of the ocean. This, which is known as the Grenville Sea, was probably the home of much larval life. Bands of graphite which are not uncommon in the limestone have been taken to indicate the presence of carbonaceous matter, possibly seaweeds. Other dark bands in the limestone were probably once ashes, ejected from volcanoes that rose out of the ocean, and settling in layers on the bottom. The Grenville Sea maintained its position for a length of time which seems almost incredible. The thickness of the limestone and associated beds has been measured at 94,000 feet, without any sign of a duplication of the strata (46); and even if one assumes the rocks to have been once sharply folded back upon themselves, the thickness would still be nearly 10 miles: the thickest record of consecutive sedimentation anywhere in the world. At the standard rate of deposition, at least 5 and possibly 9½ millions of years elapsed, during which most of Ontario was a sea-bed.

EARLIEST TRACES OF LIFE.

The traces of life in the Grenville Limestone are interesting, not only as being the earliest known, but also on account of the furious controversies which long raged over them. I have already mentioned the bands of graphite. Then there is the limestone itself, which forms over half of the total mass. Where the lime came from originally is a problem as yet unanswered; its actual precipitation was most likely derived from the chemical action of ammonium carbonate, one result of decomposing animal remains. But the principal "fossil" of Grenville times is the celebrated structure known as Eozoon. Believed at one time to be the oldest relic of life in the world, it is now generally considered to be inorganic, on account of very similar mineral structures having been found in very much younger igneous rocks. But to those who believed in the reality of Eozoon (and they were expert microscopists, of the highest reputation and scrupulousness), it was allied to the Foraminifera, which are protozoans that build up most wonderful chambered shells (Plate 85): consequently, it was on the bottom rung of animal life (47). It would have formed large reef-like masses, in roughly concentric layers, each layer containing a number of very thin leaves or laminæ, and the whole penetrated by many delicate canals (Plate 20, *4*). Each mass was a colony containing thousands of tiny cells; each cell once held a little spot of living jelly-like matter. So great a resemblance of a mineral to living structures calls for explanation; the argument against its organic origin is that limestone, changed by heat, can be shown to have assumed an identical structure.

Creation of Laurentian Mountains.

The tremendous ejections of the Keewatin volcanic epoch, and the abnormal tension in the Earth's crust that was caused by the extraordinary sinking of the sea-bed in Grenville times, thoroughly upset the globe's internal equilibrium, which was only re-established by the most violent changes. All the way from the Mackenzie River basin, past the site of the Great Lakes to the farthest point of Labrador, huge, dome-shaped masses of granite were intruded into the base of the volcanics and of the limestone. These rocks, after being badly squeezed, bent and fractured, and also in part melted away, were eventually forced up into a mountain area beside which the present rough surface of the Laurentian plateau is but a gentle plain. How high these mountains were we cannot say; but they may safely be pictured as of the greatest magnitude, for they formed a continuous chain over a thousand miles long, with a width in the centre of some hundreds of miles. There is some evidence to show that they were snow-clad, at least in the later part of their history. They were certainly gloomy, grand and barren, devoid of vegetation and animal life, and a formidable barrier between what was then a warm and genial Arctic Ocean and the equally favoured waters which presumably covered the United States. All the characteristic features of a big land—hill ranges, gorges, wide plains, streams and lakes—were undoubtedly present in this ancient world; but Time's merciless finger has wiped them out completely. We can, however, derive considerable satisfaction even from this loss; for the denudation which cut so deeply into the land has exposed its roots, and shown us how it was formed.

The Roots of the Mountains.

In parts of south-east Ontario, there are numerous well-exposed instances of the junction of the granite, as it welled up in a molten state, and the deep-lying base of the limestone; the volcanic rocks having presumably been eaten away before this event transpired. The intense heat so cracked, loosened and decomposed the limestone, that its outline became exceedingly irregular, while its texture was changed over a large area into that of coarse marble. Into every crack and hole the fiery fingers of the granite pressed, there to solidify at leisure. Blocks, large and small, of the older rocks were broken off the roof of this Hades, and *floated away* in the molten mass, where they slowly dissolved. There exist the most conclusive proofs possible of this fact, the timely cooling and consolidation of the granite having preserved a complete series of the broken blocks in all stages of melting, from pieces the angular points of which were just commencing to corrode, down to others whose detection is only rendered possible by the darkening in and different composition of the granite (48). It may be that this eating away of the base of the solid rocks by the molten magma (which permits motion in the fluid, despite the immense pressure by which it is confined), is one main cause of those vertical earth movements of which we have already noted numerous manifestations.

GREAT EXTENT AND VARIETY OF THE ARCHÆAN.

From what has been said, it will be clear that the Archæan ages, notwithstanding their comparative lack of life remains, possess an interest all their own. Nevertheless, if I am to confine this book to a reasonable space, I must reluctantly omit many curious and interesting facts concerning those times; the more so as, for the most part, they are at present wrapped up in dry technical papers and still drier mathematical analyses. Having dawdled, as it were, at one or two main stations on the Archæan Railway, we must now race at full speed past the rest.

Now, the first rocks containing any abundance or variety of fossils are called the *Cambrian*. They lie on top of all Archæan rocks. Between the Cambrian and the Archæan there is nearly everywhere a break, and in some cases, such as that at the top of the Torridon Sandstone, it is an immense one. But the gap between the Cambrian and the creation of the Canadian Mountains above referred to, is infinitely greater still. In the extensive regions bordering the Great Lakes, there were formed, during this interval, no fewer than four successive land masses, possibly all of semi-continental size. That which was initiated by the granite intrusion, which was of course the first, is known as the Laurentian; and it was folded,

Pl. 22. *E* 68.

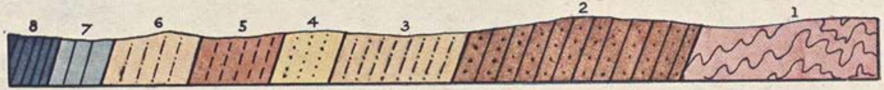
Old Faithful Geyser, Yellowstone Park.

This and similar hot springs represent the last efforts of volcanic activity. (p. 64).

(Courtesy of Union Pacific System).

A: North-West Highlands of Scotland (after Horne).

1. Lewisian Gneiss. 2. Torridonian. 3-5. Cambrian. 6. Moine Schists, etc. f.f. Faults.



B: St. Davids, Wales (after Hicks, generalised).

1. Altered rocks. 2. Basal Cambrian. 3. Paradoxides beds. 4. Menevian. 5. Lingula Flags. 6. Tremadoc. 7, 8. Ordovician Slates.

C: Philipsburg, Montana (after Calkins).

1, 2. Pre-Cambrian. 3-5. Cambrian. 6. Devonian. 7. Carboniferous. 8. Jurassic. 9. Cretaceous. 10. Tertiary Igneous Rocks. f.f. Faults.

Pl. 23. **Sections through Cambrian Rocks.** *F 69.*

fractured, twisted, worn away and enormously altered before ever a pebble of the next land was deposited on top of it. The next three periods, all of which contain considerable thicknesses of rock, separated by land surfaces of worn outline, are together known as the Huronian; typical rocks of those times having been originally observed on the north shore of Lake Huron. In one part or another of these formations, according to the locality, immense deposits of iron ore have long been worked: these have had a profound influence on the economic development of the United States. The iron is believed to have been deposited originally from water through organic action; a work in which the humble but potent bacteria probably played a part (49).

The Oldest Undoubted Fossils are Sponges.

When the Laurentian continent had been so nearly destroyed that even the granite (which consolidated deep down in the Earth) was exposed at the surface, it sank in many places beneath the sea; while in others, possibly, high mountains still existed, and glaciers carried down to the valley bottoms masses of boulders: glacial conditions may also have prevailed at the same time in other parts of the world. The new sea-bed comprised, in some parts, thick beds of shingle, containing fragments of the older rocks; but to the north-west of the site of the Great Lakes the water was clearer, and a mass of limestone was there deposited, known in one place as the Steeprock Series, because of its fine exposures on the shore of Steeprock Lake. The limestone contains great numbers of an undoubted and well-preserved fossil, discovered in 1911 by Dr. A. C. Lawson, and designated Atikokania (50) (Plate 20, *1*). The fossils represent a distinct advance on the simplest forms of life, since they are believed to be sponges. Some of them formed colonies of minute individuals, united by their body walls; others lived a separate existence, though in close proximity to their fellows. Most of the remains consist of a cylindrical or pear-shaped central cavity, whence more or less hexagonal tubes radiate, like the spokes of a wheel; the latter were perforated, and through the pores streams of water no doubt passed when these wonderful things were alive (51).

In due course the Steeprock Series became land, and in due course that land gave way to another. Elsewhere it was the same. In some localities there were two such periods, and in others three, depending upon the amount of denudation. As if to vary the tale of limestone, mud had a turn. Some thirteen thousand feet thickness of it was laid down south of Lake Superior; and far to the east, in Nova Scotia, its thickness has not been satisfactorily ascertained, though it is of the same order of magnitude. In the west, the mud yielded nothing that would aid man; in the east, veins which pierced it, long after it was elevated into land, contained gold, and have been mined for that metal for many years. The two muds may not be of the same age: there is at present no means of correlating them definitely. Somewhat similar muds, of about the same age, in South Africa, also became gold bearing, and have yielded immense values.

The Keweenawan Volcanic Outbreaks.

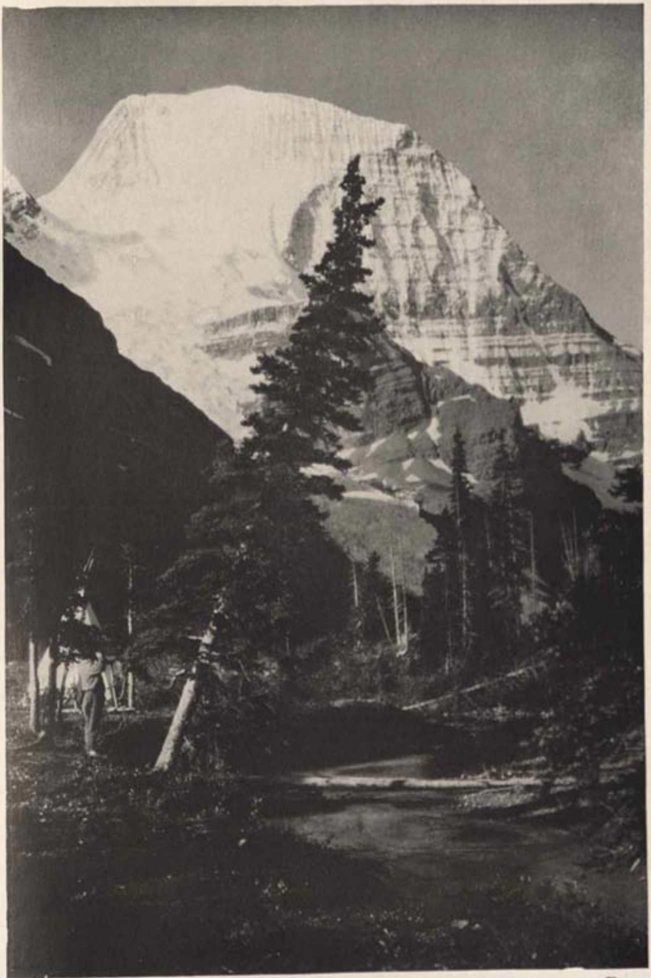
The map of Lake Superior shows a curious finger-like mass sticking up off the south shore. This is the Keweenaw Peninsula. The rocks of which it is composed, which extend right across the lake as far north as Lake Nipigon, and westwards to the site of Duluth and beyond, mark the latest stage in pre-Cambrian time; part of them may be Cambrian, but this has not been proved. They indicate a reversion to volcanic trouble, which, although by no means absent during Huronian times, had never attained to anything like Keewatin violence. We find everywhere a series of lava flows, attaining a maximum thickness of 15,000 feet, on top of which is a mass of sandstone nearly as thick. Part of this great body of rock was laid down in water, and part on land. The lava apparently came up principally through fissures, and just welled out over the surface; but it had only a moderate freedom before solidifying when it got there, for individual flows have rarely been traced farther than 10 miles from their source. Some of these huge bodies of glowing rock, however, were hundreds of feet thick. That there were considerable intervals between the eruptions is well shown by the occurrence of beach-formed and possibly river-formed puddingstones or conglomerates, each the record of a long, long time of wear and tear. These, besides being traceable much farther than the volcanic flows, are of extraordinary thickness, the greatest attaining nearly 5,000 feet (52). If, now, any one reading these lines should go to a typical conglomerate in the making, such as the Chesil Bank, and should mark its modest dimensions, he would be in a position to understand, more or less, what I mean by a "long, long time." The least interesting thing about these rocks, the Keweenawan, from a scientific point of view, and the most important from a commercial one, is that they contain very large quantities of copper, which have been mined for many years. The famous Calumet and Hecla mines are in this locality.

Western America in this Age.

For the rest of the continent in those stirring times, only a word can here be spared. They consist, very largely, of deposits along the line of what are now the Rocky Mountains, with extensions eastward in Montana and Idaho (Plate 18, c). Mainly monotonous successions of limestones and sandstones, lying on the old Keewatin lavas or their equivalents, they bear distinct impressions of having been formed very largely on river plains, in continental lakes and on sheltered coasts, rather than out in an open ocean. Many of them were undoubtedly once mud flats that ran far out into the water, being uncovered at every tide; for they exhibit, with marvellous clearness, impressions of ripple marks, sun cracks and salt crystals that were formed in the evaporated pools. At times, life was very abundant here, though not very much of it has come down to us. A great many fragments of a small, shrimp-like crustacean, called Beltina, have been found (Plate 20, *5*), besides many Cryptozoans, which were colonies of tiny protoplasm, aggregated together in cabbage-like masses (Plate 20, *3*). Of the bacteria that were detected in these rocks I have already spoken. Then there were various algæ or seaweeds, not too well preserved on the whole. Finally, it is highly probable that here was the breeding ground for many of the wonderful forms which were soon to adorn the Cambrian seas; for, sheltered from the elements and in part protected from each other's depredations, no better place for animal development could be conceived. Could we, as with a magician's wand, step there in an instant, we should be dismayed by the wind-swept desert aspect of the shores, and delighted by the curious larval forms in the water.

THE ARCHÆAN WIDELY DISTRIBUTED.

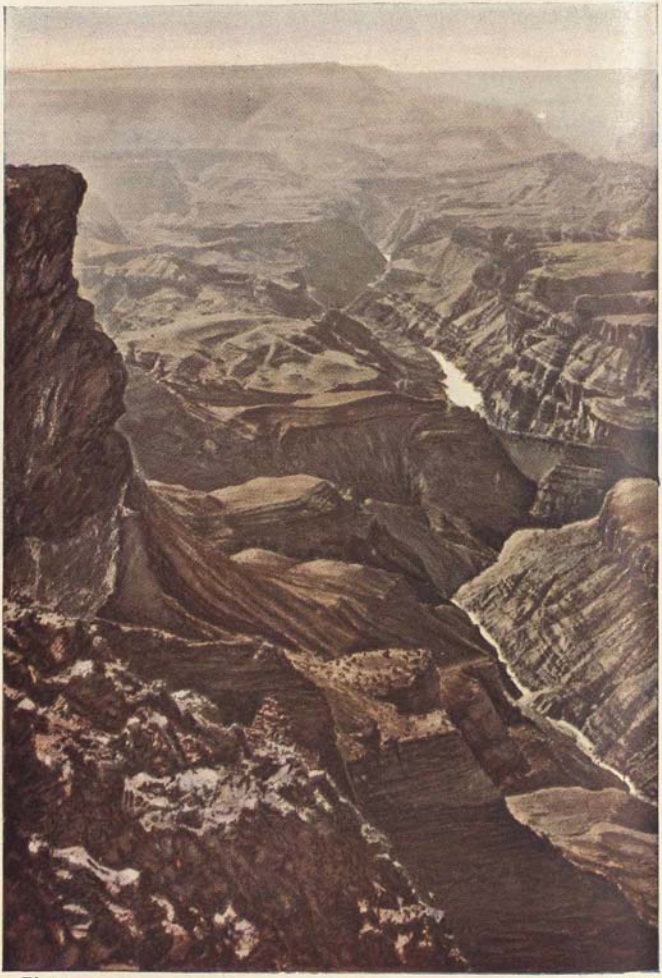
Here we must stop. A more or less similar story will doubtless be told of other parts of the world, when sufficient facts have accumulated. But geology, like all the other sciences, is really only in its infancy: the sum of what is known about the Earth is as a thimbleful of water when compared with the ocean of the unknown. All that can be said now is, that similar, very ancient rocks cover a large part of Africa; that a curiously parallel succession of ages to the American one has been observed in China (53); that fragments littered over southern Asia and Australia make up the wreck



Pl. 24. *F* 72.

Mt. Robson, 13,068 ft. Rocky Mts.

A precipice 10,000 ft. high, nearly all Cambrian rocks (p. 80).



Pl. 25. *F* 73.

Grand Canyon, Colorado.

Horizontal platform (Tonto) of Cambrian Sandstone (p. 77).

of a continent long since gone to ruin (Plate 18, B); and that rocks of similar appearance but unknown age make up the foundations of Antarctica; while in the icy north, the great bulk of Greenland is made up of rocks that are undoubtedly Archæan (54).

CHAPTER III.

The Age of King Crabs (*Cambrian*).

THE NAME "CAMBRIAN."

ANYTHING that comes from Wales is known as Cambrian; and as a large part of Wales is underlain by exceedingly old rocks, which overlie the ancient deposits recorded in the last chapter, the name of Cambrian was, many years ago, applied to them. It has since come to be given to similar old rocks in many parts of the world; and it represents some two millions of years, measured on the foot-per-century scale.

ALTERNATIONS OF SEA AND LAND.

Now, when considering the geography of former ages, one important fact must never be lost sight of, *i.e.* that what is now land was then usually sea; for it is only because it is land now, that we know anything about it. One cannot search the rocks which lie under the ocean; and only biologists can hint at possible land connections across wide marine basins, in explanation of the existing distribution of animals and plants: from the geologist's point of view, such areas are blanks. Thus, in regard to ancient lands and seas, one is always combating, mentally, instinctive objections to considering the one as the other; though of the fact that land has been sea, and sea land, repeatedly in the Earth's history, the rocks and their contents bear conclusive testimony. One other remark seems called for at this point. One must perforce speak of a land as extending from A to B in such and such an age; but this is only in a general sense: the land did not necessarily have that extent for *all* the age, but only for a *part* of it. This will be obvious if one remembers that shorelines, even in our own days, are in a continual state of oscillation; and of course, in the enormous periods of time that make up a geological "Age," these oscillations attained very large proportions. Thus, events which in a general sense are contemporaneous, are by no means exactly so. We find a shell at Birmingham, and another one of identical aspect in Nova Scotia; nevertheless, the one may be much older than the other, although they both lived in the same *age*.

SKETCH OF CAMBRIAN GEOGRAPHY.

Taking a general survey of Cambrian times, we find that in the early stages a large island or elongated continent extended from northern Scotland to Scandinavia, and possibly across what are now the tundras of North Russia; thence, the coastline passed through the heart of Russia and across Bavaria and Bohemia, with peninsulas stretching northwards and almost enclosing arms of the sea. From Bohemia, the shore crossed the site of the Alps into central France and to Spain. Far to the west and north-west of this land lay a second one, its eastern border running through the Atlantic counties of Ireland; this land stretched northwards towards Iceland and Greenland, and southwards and westwards for an unknown distance. It seems very possible that much of the North Atlantic was at this time dry land, and that a shore may have stretched right across to the borders of Labrador. In the large landlocked seas which thus covered north-west Europe, were a number of islands, particularly in Shropshire, in the Malvern Hills, in Charnwood Forest, in Wales, and in the Ardennes. The Highlands of Scotland were humble lowlands, and, in part, completely submerged. Islands and mainland alike were probably barren wastes of sand and decomposed granite;

exposed for ages to a hot sun and scanty rainfall, the rocks had utterly rotted away. At the beginning of Cambrian times, however, the rainfall must have increased; for considerable streams, laden with this arenaceous waste, began to strip it off the land and dump it into the neighbouring shallow sea. The fact that the various bays and estuaries were protected, seems to have had a peculiar effect in stimulating the growth of living creatures; the sea now became tenanted with a singularly varied series of animals, to which I will refer in detail later. All the time that the mud and grit were pouring into the sea, the sea-bed was subsiding. This went on in Wales until no less than 12,000 feet of grits and sands were deposited (Plate 23, B), entombing a long succession of different animals; but in some parts of the sea, as in Gothland, the ocean bottom scarcely moved, and as the currents avoided that locality, practically no sediment was deposited there: thus, the great thickness of Wales is represented there by only 200 feet. It seems to have been a general phenomenon of the age for greater stability to lie towards the east; for beds which in Asturias are 10,000 feet thick, have representatives in Bohemia that are only one-sixth as much.

At this time, Newfoundland, on the other side of the Atlantic, was submerged; and between it and Europe ran either a shoreline or a belt of shallow water; for many remains of crawling things have been found in the two localities, 1,800 miles apart, which are identical in structure, and must, therefore, have freely intercommunicated, both as free-swimming larva and as adult forms. The route of the modern liner was that of the ancestral crab.

THE CAMBRIAN OF AMERICA.

The Newfoundland Sea washed only a small part of the North America of those days, the continent, though quite as large as at present, having a vastly different shape. What are now the many-ridged Appalachian Mountains were then the bed of an interior Cambrian Sea, and were bordered on both sides by long tongues of land, extending from north-east to south-west; of these, the easternmost was much the higher. The southern part of the Mississippi basin formed a shallow bay of the sea, to the north of which lay the great mass of the continent, as at present, only with no Great Lakes and with different drainage ways. There was also, possibly, some continuation of the Keweenawan volcanic episode about the site of Lake Superior. As time wore on, the sea gradually advanced up the Mississippi Valley, until in the course of ages its waters washed the shore of Wisconsin, of Michigan, of Minnesota, and finally, after drowning these States, ended against the low but unbroken margin of the old Laurentian land. At about this time, in all probability, the long straight line of the St. Lawrence River first took shape, as a wide ocean channel between the interior Appalachian Sea and the restricted Atlantic, and debouching into the latter somewhere between Cape Breton Island and Newfoundland (55). Its cause was a line of weakness in the Earth's crust, along which fracturing and subsidence took place. It is thus one of the oldest geographical features now to be found on the globe.

The western part of the continent formed a similar mixture of long, shallow bays intersecting the land, with the important difference that there was no water communication with the Pacific—at any rate, in the northern regions. Under favourable conditions, too, the sea was clear in places, enabling limestone to form (Plates 23, C; 24, 25). In these western waters, many curious and beautiful creatures flourished, some of the remains of which have come down through the changes of many ages, with even their internal structure marvellously preserved.

In the far north of America the record fails us. It may have been, in the main, a part of the Laurentian continent. It is highly probable, too, that in place of the swamps and treeless barren grounds of the North, there was a climate as mild as that of Central Europe; but the fair tracery of vegetation had not yet come to adorn the Earth.

Parts of the interior of Brazil and of the Argentine were a sea-bottom in Cambrian times; but the boundaries of this sea are not yet well known. It is possible that then, as at a much later time in the world's history, the deep waters of the South Atlantic had no existence, and that a continuous land bridge extended from the highlands of Brazil to the Guinea Coast, and thence into deserts as arid and barren as anything that Africa has to show to-day. It is certain that much of Africa itself was high and desolate, either wholly waterless, or subject to occasional cloudbursts which were insufficient to form perennial streams.

Antarctica probably then Land.

What was going on all this while in the vast and little-known wastes of Antarctica? Nobody knows. The mantle of ice which holds it fast conceals much that will be one day common knowledge among men; but from the fragmentary knowledge gleaned by the sufferings and exertions of a handful of brave men, it appears that this territory, which is as large as Europe, was possibly land in Cambrian times, and for long after. It is very unlikely that any great degree of cold existed there; nevertheless, the contortions of the old rocks suggest that it may have been mountainous; and in the higher parts of such mountains glaciers might develop.

Asia and Australia.

In the East, no one would recognise the Indian Ocean, the Indies or the China Sea, for they were not there. In

Archæan times a continent stretched there, whose bounds are not known ; but fragments of it have been recognised in much of China and peninsular India, and east as far as the interior of Australia.

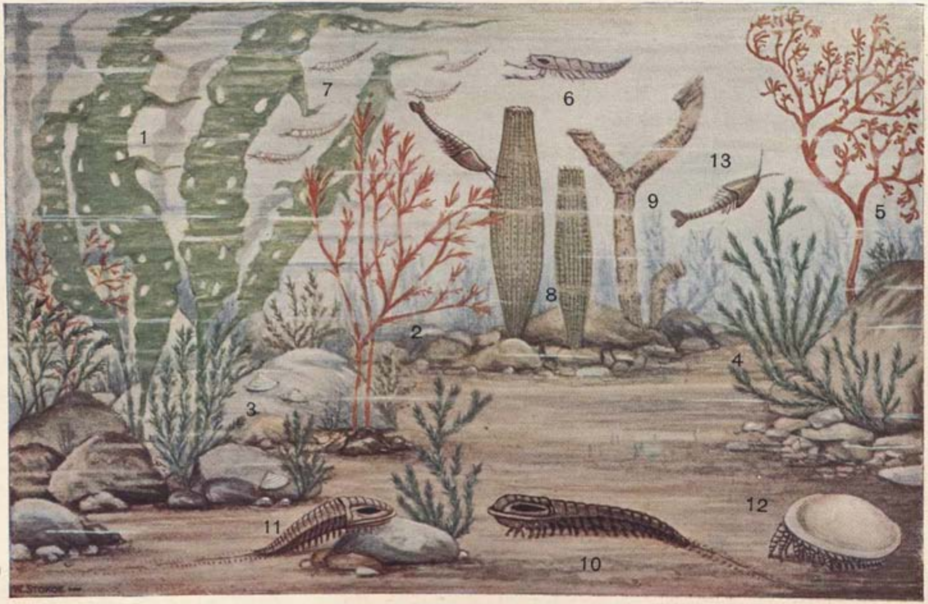
During Cambrian times this continent began to go to pieces. Primarily, the ocean invaded it from the north, burying southern Siberia, by way of the Lena basin and that of the Yenesei. A little later, marine waters encroached upon China and Manchuria : Shan-tung, Shan-si, and part of the tangled knot of mountainous ground in Burma, succumbed in turn. Peninsular India, apparently, was subject to torrential visitations of rain ; and in the desert valleys and broad featureless plains, great deposits of gravel, mud and sand were spread out by floods after cloudbursts. A long arm of the sea, however, found a way into this wilderness by the Salt Range and the Punjab. The mighty Himalaya, huge and immovable though it may seem to the perspiring tourist, was as yet unborn ; and its site was the home of insignificant crustaceans and humble shells. Far away on the other side of Gondwanaland, the sea was also nibbling at its shores ; as is evidenced by deposits of this age about Adelaide, in the Northern Territory of Australia, and in Tasmania. New Zealand was at that time, like the Himalaya, off the map.

An Age of removing Rubbish.

So much for Cambrian geography. Taken as a whole, it makes up a strange world, and one that we should have much difficulty in recognising. It was different, also, in other respects. For instance, the climate was probably as warm over the whole globe as it is at present in sub-tropical regions ; and the belts of heat and cold, which are so strongly influenced by the distribution of sea and land, may not have been so sharply differentiated. Then, again, volcanic eruptions were practically nil. The efforts of prior ages had damped down the internal fires; the work of the climate had reduced the rocks to powder: Cambrian time thus became a removal age, on a great scale, for the rubbish that had long accumulated on the surface. This rubbish, sorted and piled in stacks by the sea, like rolls of cloth in a well-kept shop, now confronts us in the wall-like precipices of the Rocky Mountains (Plate 24); peeps out in the iron-bound shore of Harlech; hides itself unobtrusively in river cuttings and well-sinkers' records; or glares at us in the candle-snuffer summits of the Highland peaks (Plate 23, A). If we lift up a few folds in the rolls of cloth, we find, at irregular intervals, marks and smears. They are the records of the time, so far as life is concerned; and they confirm our impressions of its singularity.

CAMBRIAN LIFE ENTIRELY MARINE.

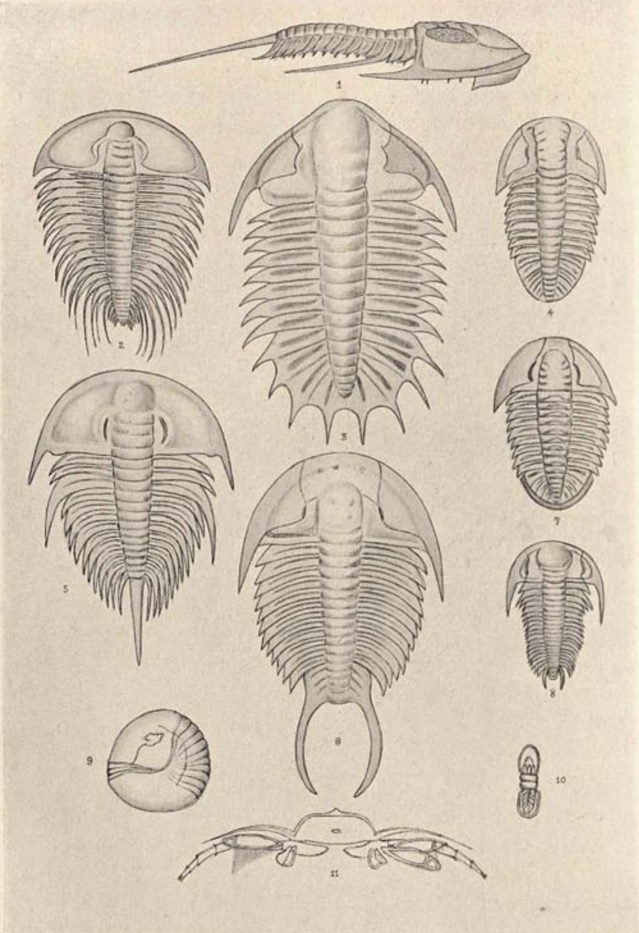
Cambrian life, as found fossil, was wholly marine. One principal reason for this is, that organisms which are buried under water are protected from the rapid dissolution induced by the atmosphere. Another reason, unproven but almost certainly true, is that land life was still nearly as primitive and scarce as in pre-Cambrian times; and although it was sufficiently in evidence during our next Age, the Silurian, to justify a long ancestry, there must have been, prior to that age, a "something in the air" that hindered, or possibly quite prevented plant development. This striking absence of terrestrial remains is one good reason for believing that the climate was hot, dry and not subject to much variation; for the growth of plants in the next age was in oceanic islands, and was doubtless much influenced by their humid atmosphere. If we were to camp, in fancy, upon a Cambrian shore, we should doubtless be appalled by the barren loneliness and the dry and lifeless aspect of the place.



Pl. 26. *F* 80.

Cambrian Life in the Wapta Pool (pp. 84-87).

1-5. Sea Weeds (1, Morania ; 2, Dalyia ; 3, 4, Marpolia ; 5, Waputikia). 8-9, Sponges (8, Takahbaria ; 9, Vauxia). Crustaceans (6, Leanchoilea ; 7, Yohoia ; 10, 11, Bathyuriscus ; 12, Hymenocaris ; 13, Waptia).



Pl. 27. *F* 81.

Cambrian Trilobites (pp. 81-83). 1, 5. Olenellus. 2. Nevadia. 3, 11. Neolenus. 4. Bathyuriscus. 6. Crepicephalus. 7. Coosia. 8. Paradoxides. 9. Illænus. 10. Agnostus. (2-7, 11, after Walcott; 9, after Nicholson).

But in the sea it was very different. Beneath those favoured waters, in sheltered bays and inlets, life abounded. Its remains have come to us in a scattered and fragmentary state, often with great gaps between successive groups of remains; but it is certain that the whole age was highly favourable to marine existence. There were many seaweeds, worms, molluscs, starfish, crustaceans, jellyfish and ancestors of the modern Hydra; and towards the close of the epoch, the first members of the nautilus and the octopus family made their appearance. These may seem low forms of life, when superficially considered; but they are of extraordinary complexity, when we remember that the simplest form of life is a mere speck of jelly, not even confined in a cell, whose sole evidence of existence is the repeated subdivision of itself by splitting into halves.

The Trilobites, or King Crabs.

First of all, we will glance at the Trilobites, the most typical and numerous animals of the age (Plates 26, 27).

They were probably crustaceans, of a type somewhat resembling the existing Horseshoe or King Crab, and were originally an off-shoot of the marine worms, armoured, and adapted to crawling on muddy sea-beds. They varied in size from ¼ inch to 2 feet or more. Even the most primitive of them was a very complex animal, known as Nevadia (Plate 27, *2*); the most highly developed were very specialised creatures indeed. The animal's body was divisible into three lobes—hence its name; and was more or less oval-shaped: it was divided into many segments, like a worm's. It always had a relatively large head, and sometimes this feature was as large as the body. Both head, back and tail were protected by shields of varying forms, which grew together into one horny covering, sometimes extremely flexible, so as to enable the trilobite to coil itself up like a woodlouse (Plate 27, *9*). The eyes were large and very complex. The animal was of sociable habits, living in considerable families near sandy or muddy shores; but some adventurous spirits swam about gaily in the open sea, and thus distributed their kind far and wide.

Habits of Trilobites.

According to the late Dr. Walcott, who made a monumental study of these creatures, their

> "strong long legs enabled them to crawl rapidly over the surface of hard or moderately compact sediments, either under water or over the wet surface of the beach between tides. When searching for worms, their principal source of food, they evidently worked down into the mud, very much as the horseshoe crab does . . . forming deep trails and half burrows which, when made in moderately stiff clay or arenaceous mud, retained the form of the trail and burrows until the next tide or current filled them up and a natural cast was formed; these trails and casts occur in great numbers as fossils" (56).

When swimming, some species may, like the horseshoe crab, have done so upside down, and probably they rested in the same attitude on the bottom; for Dr. Walcott found, in one instance alone, that out of 1,160 specimens no fewer than 1,110 were lying on their backs (57). But part of this reversal of the natural order of things may be due to the expulsion of gases from the body after death. Like other crustaceans, the trilobites propagated their kind by eggs, which were laid in tremendous numbers; and as they were the lords of creation in those days, a large proportion of the eggs were duly hatched. It was not, in fact, until near the end of the Cambrian, when they had been in existence for perhaps a million years, that the domination of the trilobites was seriously endangered by the development of a more formidable creature.

Variety of Trilobites.

Of the great variety of trilobites, we can here only mention a few. The genus Olenellus (Plate 27, *5*) is interesting, as it is usually connected with the oldest assemblages of organic remains in the Cambrian; but even this form persisted for hundreds of thousands of years without any marked change. Nevadia (Plate 27, *2*) should also be specially noted, as it is the most primitive trilobite known (58); Paradoxides (Plate 27, *8*), which typified the later stages of Cambrian time, and flourished greatly in Wales; and Agnostus (Plate 27, *10*). There is, it may be added, an almost complete series of trilobites, from the simplest to the most highly specialised. Their remains have been found in countries as far apart as Britain and South America, or Newfoundland and Australia. This generous preservation is due, in the main, to their horny shields being almost indestructible fossils; even in rocks that have been greatly distorted by pressure, the impressions of trilobites, misshapen but otherwise clear, have been found.

Other Cambrian Crustaceans.

There were also present in the Cambrian seas numerous other crustaceans of various types. The bulk of them were more or less shrimp-like in aspect, usually with very large head shields or carapaces; and they rarely exceeded 3 or 4 inches in length (Plate 26, *6*, *7*, *13*). But eventually two lobster-like creatures (Eurypterids) arose, having a length of some 9 inches, and possessing a taste for trilobites which was to prove fatal to many of that family in the next two ages. For the nonce, the Eurypterids were content merely to grow; later on, we shall find them developed into nightmares of creatures up to 9 feet long (Plate 38, *7*).

SUGGESTED ORIGIN OF CRUSTACEANS.

Before leaving this part of our subject, we must just refer to the interesting theory of Mr. H. M. Bernard, that the crustaceans as a whole originated from a browsing, flesh-eating segmented worm, the first five segments of which were bent down so that its head looked towards its tail. Singularly enough, Dr. Walcott found actual fossils which tend to support this hypothesis (59). In any event, one must look for the origin of trilobites far back in the pre-Cambrian.

WONDERFUL DISCOVERIES OF SOFT-BODIED CREATURES.

Until quite recent years, it was believed impossible that any soft-bodied animals could be preserved in such ancient rocks as those with which we are dealing; but the chance discovery by the indefatigable Dr. Walcott, in 1909, of a block of shale that a snowslide had brought down near Field, B.C., and which was full of fossils, led to an investigation which resulted in enriching our knowledge enormously. All kinds of remains, from the most delicate ringed worm to the hardest-shelled mollusc, were discovered in abundance; to such a degree, in fact, that no fewer than fifty-six different *genera* of crustaceans alone were unearthed from a block of shale not over 6 × 7 × 40 feet (60). It appears that in this vicinity, in mid-Cambrian times, there was a small, much-sheltered bay of the sea, into which, in addition to its own life forms, the remains of other organisms were washed by gentle currents. Here, amid the long waving tufts of seaweeds, crustaceans darted nimbly to and fro; jellyfish floated in and out with the tide; and molluscs settled snugly down on the muddy bottom (Plate 26). The illusion is destroyed by the practical certainty that this mud was fetid, being heavily charged with carbonic acid gas; and as the dead organisms sank into this, they were immediately preserved, as in a vacuum, from decay of any kind. Our knowledge of many of the Cambrian animals is, unhappily, largely confined to this one small spot; but when we consider the uniform conditions which prevailed, and the apparent similarity of all the Cambrian seas to one another, we can hardly doubt that elsewhere similar weeds and jellyfish floated about, similar worms and primitive echinoderms had their being. That they have not been preserved, as a general rule, is only to be expected, for ordinarily they are incapable of preservation.

Cambrian Seaweeds.

If we glance first at the algæ, or seaweeds, we learn that the greatest, and most abundant, was a form closely allied to the modern blue-green algæ, and named Morania (Plate 26, *1*). There were also various beautiful red and green weeds. Some types were gelatinous or leathery; others had delicate thread-like fronds, or else formed long chains of oval or spherical air-bladders. Others, again, were floating rafts, the homes of many annelids and small crustaceans (61) (Plate 26, *1–5*).

Cryptozoans.

Another simple form of life which then abounded, the Cryptozoans, formed colonies of minute individuals, each of which was connected by living matter to the others. They grew up into more or less cabbage-shaped masses from a stump or stalk; the mass was penetrated by a network of radiating canals and tubules (*see* Plate 20, *3*). In some instances, these fossils present a marked resemblance to certain inorganic arrangements of minerals, and they are for that reason always regarded with a certain amount of suspicion.

A Cambrian Sea Cucumber; and a Jellyfish.

Near Field, B.C., among other things, was found the oldest echinoderm—the first complete specimen of a sea cucumber, in fact, to be discovered in any formation. It had a soft, depressed umbrella-shaped body, with radial lobes like a jellyfish. It probably lived in quiet and sheltered bays, where it grew to a diameter of some 6 inches. By its side was found the oldest known true jellyfish (Peytoia), surrounded by marine worms and crustaceans, and also, doubtless, thriving in those quiet waters (62). The oldest Stone Lilies or Crinoids are also Cambrian; they did not develop greatly, however, until the next age.

Great Variety of Sponges.

There were many sponges in Cambrian times. Our ordinary conception of a sponge is the article that we find in our bathrooms; but this is only one of the vast number of different kinds—globular, tubular, plate-like or irregular in shape; soft, stony or glassy in texture. They inhabit, and, so far as is known, always have inhabited, very varying depths of water: though, with one exception, all marine, they may be found on the shore, or down in the abysses, or anywhere between the two; but each kind has its special habitat, to which it is often marvellously adapted. Sponges are the most primitive animals except the Protozoa, being colonies of cells living in a communal way, but incapable of locomotion, and having no organs of sense or reproduction. They obtain their food by exciting currents in the surrounding water by means of innumerable hair-like bodies that line the pores of their home, and thereby drawing in minute particles of food: this food is absorbed bodily by the cells which line the pores or canals.

Atikokania, the oldest known fossil (Plate 20, *1*), is believed to be allied to a sponge. But although its antiquity is so great, the sponge is not usually capable of preservation, the only parts found fossil, as a rule, being the minute and variously shaped spicules, made of silica or lime, which supported the fabric in life. But from the Wapta Pool (as the Field locality is called), and also from Wales, Cambrian specimens have been obtained where the outer skin has been replaced by iron pyrites. Some of the Field specimens were very large, certain tubular varieties reaching a length of 40 inches, or even, exceptionally, 50 inches (63). From this, they ranged down to small sponges of globular or vase-like outline (Plate 26, *8*, *9*). It is interesting to note that no less than sixteen different genera came from this one locality; a sure indication of a long antiquity in pre-Cambrian days.

Fossil Worms.

Marine worms were also common. Their remains form flat films pressed out on the rocks; and their devious courses have been stamped indelibly throughout the ages, by tube-like burrows or serpentine trails in the mud (Plate 20, *6*). 12 different genera were found at Field, B.C., some of which had a distinct head, though others had not attained that dignity (64). In the succeeding age, marine worms' jaws, which are horny, and usually the only parts capable of preservation, have been found in great numbers; but they are very rare in the Cambrian rocks, and not easy to find anywhere on account of their minuteness. Fossil worms are excessively rare. It is a wonderful circumstance that, in some of the Field specimens, even the delicate internal organs can be made out quite clearly; and our wonder cannot but increase, when we reflect that there is nothing more easily crushed out of existence than a worm. Many millions of years have they lain there, in that hardened mud; and for a great part of the time, high up on a steep mountain side, within a few feet of the weathering influences that would have destroyed them, but for Dr. Walcott's fortunate discovery.

SEA-SHELLS AND LAMP-SHELLS.

Of Molluscs, or sea-shells, and Brachiopods, or lamp-shells, it is very difficult to say much without becoming technical. They are of the greatest possible importance in the Stone Book; but for the general reader they can have but little interest, except such as are distant relatives of the familiar forms that beautify our shores.

VAST ANTIQUITY OF LINGULA.

One of the oldest lamp-shells must be mentioned particularly, however, and that is Lingula: a hoary old fossil whose years are countless. All genera of sea-shells are slow to respond to physical changes; but sooner or later, most of them give way to new and more highly developed forms. Lingula, however, has persisted practically unaltered, from Cambrian times right down to the present; and even an expert would have some difficulty in distinguishing the modern from the most ancient form. The modern Lingula burrows in the sand on coasts, and retires within its burrow in times of danger. Two other very ancient lamp-shells which have representatives still living are Crania, a limpet-like shell, and Discina, a horny little shell, shaped like a number of concentric rings drawn by some idle schoolboy. These survivals are the more surprising, since most of the lamp-shells have long since perished; of the 6,000 fossil species only some 150 still remaining.

GENERALISATIONS ON LAMP-SHELLS.

The lamp-shells are all marine, and live in all depths of water down to as much as 23,000 feet; one easily remembered distinction from other sea-shells is that the shell has two nearly equilateral valves, shaped like the top and bottom of an Aladdin's lamp, and fitting on to the animal back and front; in bivalve molluscs the shell fits on to the animal's sides.

The lamp-shells came into being not long before Cambrian times, in all probability; for although the four orders into which they are divided are represented in the oldest Cambrian fossils, it is only by primitive types. The original shell was smooth and devoid of ornament; the sculpturing which beautifies so many of them, and the shape of an ancient lamp which some forms possess, came later. A striking testimony to the truth of evolutionary doctrines is that the simplest of the four orders is that which developed first, and that the main development of the other and more highly specialised kinds took place at successively later times, in correct chronological order (65).

Complexity of Structure of Molluscs.

When we get to the molluscs, we have ascended a very long way in the scale of animal complexity; for the highest of molluscs present numerous affinities to the lowest animals possessing a backbone or vertebral column. Simple though a whelk or an oyster may seem to one who casually kicks its shell upon a beach, it is yet, in fact, a very maze of biological complexity: for the molluscs have a heart; they have a sort of tongue, with multitudes of teeth; they have eyes, varying in complexity up to those of vertebrated animals; and their principal nerve centre is in the same position, relative to the body, as is that of a lion or a man.

Ancestors of the Nautilus.

The most highly developed molluscs are the Cephalopods (head-feet), which are represented in our days by the Pearly Nautilus, the octopus and the squid, and by a very great number of differing forms in the past. Some of the more formidable existing Cephalopods, such as the cuttle, are naked; but the older forms all had the body enclosed in a shell which was built up or secreted by the animal; the creature's mouth being, naturally, at the aperture of the shell, while from the same point projected a number of sinewy arms, usually more than ten, by means of which the animal obtained its food. At first, these arms were bare; but later they acquired suckers, and thus rendered their possessors one of the most formidable dangers of the sea. Although Cambrian rocks have yielded but few ordinary molluscs, there is plenty of proof that towards the close of the age there were numerous Cephalopods. The latter lived in straight shells, slightly tapering; and as the animal grew, its body moved up in the shell, and periodically built a new compartment, completely evacuating the chamber last in use (Plate 31, *9*). The shell thus came to be divided by a number of partitions or septa into many empty chambers, and one in use. Under favourable circumstances, this process of house-building went on until the shells attained a gigantic size: one kind (Actinoceras) possessed a shell some 10 feet long by 11 to 12 inches in diameter. It is somewhat of a puzzle to know what the creature did with its huge empty house, which must, at times, have been more showy than beneficial.

CHAPTER IV.

Ages of Mud (*Ordovician and Silurian*).

If, wandering among the green hills of south-west Wales, we keep our eyes riveted on every cliff, gully or cutting, we shall find that we are in a land of mud. Slaty rocks frown upon us from every side. Slaty debris, dry or wet, is beneath our feet. Blue, black and purple, the beds seem to bend in every direction, yet without those contortions which are characteristic of metamorphic rocks ; and if we trace out any particular bed, we are sure, after a short distance, to find it end in a fracture, where some other rock, very similar, but not the same, takes its place. The similarity of all these rocks is so great that geologists were for many decades unable satisfactorily to determine their relations. Now, a man in a shop, with piles of books about him, issued at various dates, and wishing to classify them chronologically, would impress on each some little mark or sign, to enable him correctly to correlate each pile. That is what Nature has done with these slates and shales. She has marked them, with impressions very much like those of a pencil, a different set of impressions for each division of time. The impressions are of small animals that once swam in the sea. They are confined rather rigidly, each one to a specific zone ; and their discovery has made possible the elucidation of a considerable part of the world's history. The rocks that they occupy lie upon Cambrian or older formations ; sometimes, by transition upwards, indicating a gradual change from the one age to the next; sometimes there is a sharp break, indicating that the ancient land had been uplifted, worn down, and again depressed, ere the new age came in. In general, the Age of Mud commenced with a further depression of the sea bottom; for in place of the coarse grits and sandstones which had accumulated along the early Cambrian shores, we find accumulations of finer detritus, such as would be swept away by currents and deposited in water 100 to 200 fathoms deep.

Wales a Land of Mud and Fire.

Starting our examination of this mud in Wales, where it is, perhaps, commonest, we get a conception of low islands with muddy shores, interrupted occasionally by bosses of the old pre-Cambrian rocks; shallow water, with mud on the bottom and at the top, stretching across the Irish Sea, over the Dublin district, and north across southern Scotland and the Lake District. Very early in the age, volcanic action, which had been quiescent here for perhaps a couple of million years, now burst forth again: at first feebly, like a pickpocket taking purses, then on a grander and grander scale, like a successful company promoter floating new enterprises; culminating in a final terrific outburst; after which, like the imprisoned speculator, it disappears. Islands which were probably composed entirely of lava flows, with relatively little pumice or ash, reared their heads higher and ever higher above the muddy waters. At a relatively early age, such a volcano came into being off Milford Haven; Skomer Island is its worn-down stump (66). When at their greatest, the volcanoes were so active that the heart of Wales literally took fire; eruptions on the grandest scale announced the birth of mountains, such as Cader Idris and the Moelwyns, which now form the roughest part of the country (Plate 28).

Pl. 28. *G* 92.

Cader Idris, a Volcanic Remnant of the Silurian Age (p. 92),

Photo. The Photochrom Co., Ltd.

Pre-Cambrian and Metamorphic Rocks.

Cambrian to Permian.

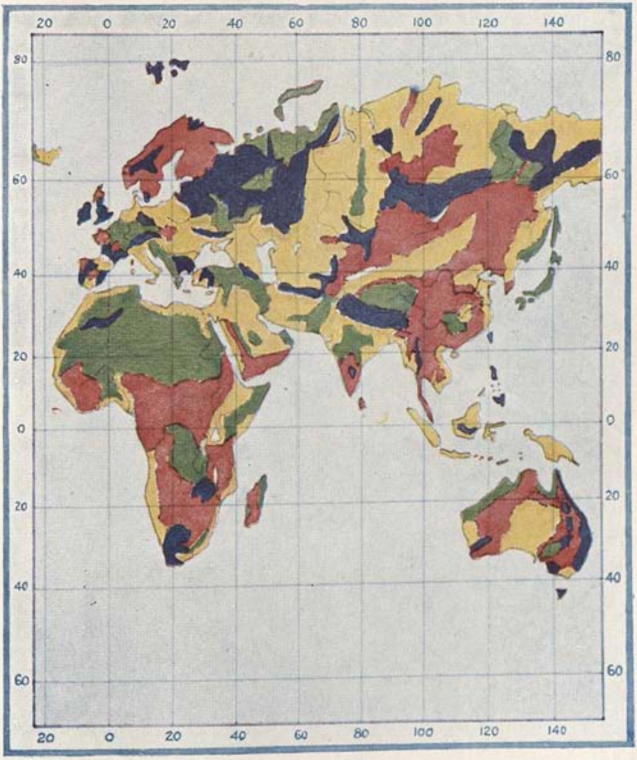
Pl. 29.

Geological Map

N.B.—Owing to the very small scale, it has only been possible to delineate the formations in the most general manner.

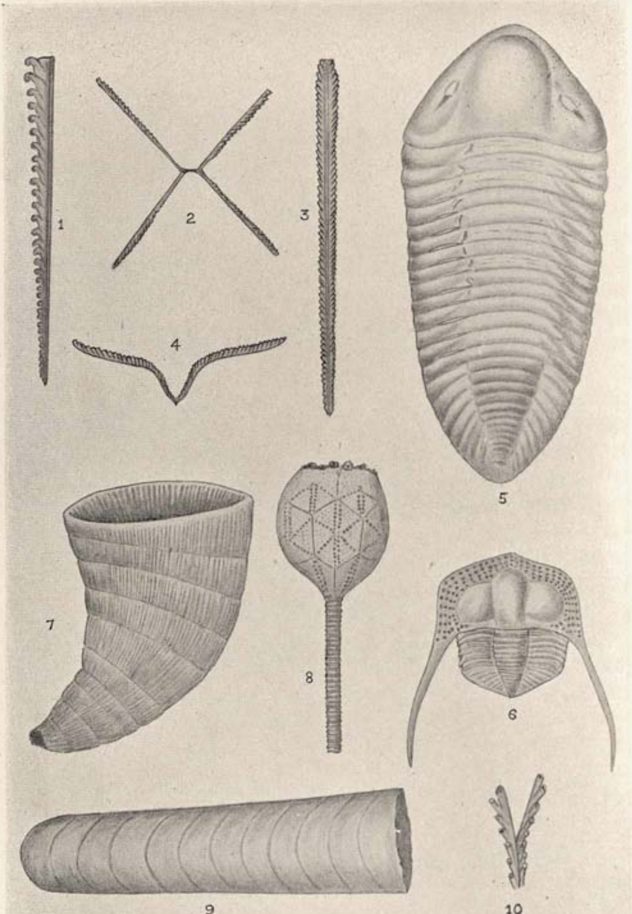
Trias to Cretaceous.

Eocene to Recent.



Pl. 30.

of the World.



Pl. 31. *G* 93.

Silurian Life Types. 1, 4, 10, Graptolites (1, Monograptus; 2, Tetragraptus; 3, 10, Diplograptus; 4, Didymograptus). 5, 6, Trilobites (5, Homalonotus; 6, Trinucleus). 7, A Coral, Zaphrentis; 8, Caryocrinites; 9, Orthoceras

Wealth of Life in the Sea.

This was an exceedingly long age. The beds of mud, now, in the main, thin slates and bands of ash, aggregate over 10,000 feet in thickness; and originally they were much greater, for compression and drying has reduced their volume, perhaps by as much as 32 per cent. (67). Thus, at the standard rate, one and one-third millions of years elapsed in this episode, during which that part of the world was a Mud Factory. The seas, too, were crowded with life; and there was a great development of new forms of creation, which were presently to bud out in many different directions. Trilobites abounded, and grew fat and of large size. The surface waters teemed with the little pencil markings which are now found on the mud-stones; these being tiny lines, like crude boats, wherein a number of little polyps in cups gaily steered a course through life (Plate 31, *1–4, 10*). Occasionally, too, gigantic ancestors of the octopus prowled around the dark corners of the rocks, waiting to pounce on any unwitting victims who should stray that way; but most of the animals were small and inoffensive. Fishes were still unknown.

Volcanoes of the Lake District.

Meanwhile, part, at least, of the Lake District and the Cheviots had become dry land, whereon a number of volcanoes became established, the activities of which went on unchecked for many thousands of years, piling up lava flows and cinder-heaps to a height of many thousands of feet.

Could we but walk about that land in fancy, we should find ourselves surrounded by one or two large and a vast number of small conical hills, on the highest of which we might find gleaming white snow in one case, and wreaths of black smoke in another. We should find the air sulphurous, and the surface rough and slaggy, with red and yellow streaks or stains upon the black slopes of the cones. A few geysers would probably be located in the vicinity of such volcanoes as were becoming extinct; and beyond their sinter-encrusted rims, we should find a few scattered weeds, a few animalcules, a little moss and some bedraggled and primitive ferns. The atmosphere would be alternately stuffy and damp, due to the semi-tropical heat and the heavy rainfall. In the old craters of dormant or extinct volcanoes, the accumulation of the rainfall would gradually create lakes (68), which would form gems of turquoise blue in this arid desert. It is doubtful whence the prevailing winds would blow; but in Wales they were certainly from the south-west, which may possibly indicate that the Atlantic then, as now, was open water. This last very interesting conclusion was deduced by Sir A. C. Ramsay from the fact that the piles of volcanic dust tail off to the north-east of the old craters, whilst to the south-west they are meagre and inconspicuous (69). The existence of the lakes is shown by the water-laid deposits which now rest on their sites. In the southern part of the Lake District, around Kendal, many of the eruptions at this time were submarine.

Earliest Radiolarian Rocks.

The supply of mud into the Welsh and Scottish seas, though huge, was not inexhaustible. At times, and sometimes for very considerable spells, the sea cleared, the volcanic islands were in part submerged, and layers of limestone carpeted the ocean floor. Herein dwelt, amid a wealth of other forms, the earliest corals—tubular ancestors of a family which has only in modern times reached its maximum development. At this time, Cornwall was among the submerged districts; and there, as in southern Scotland, in the blue waters of a deep sea, minute and exquisitely beautiful animalcules flourished in countless multitudes (Figs. 3–5). From the generally radial

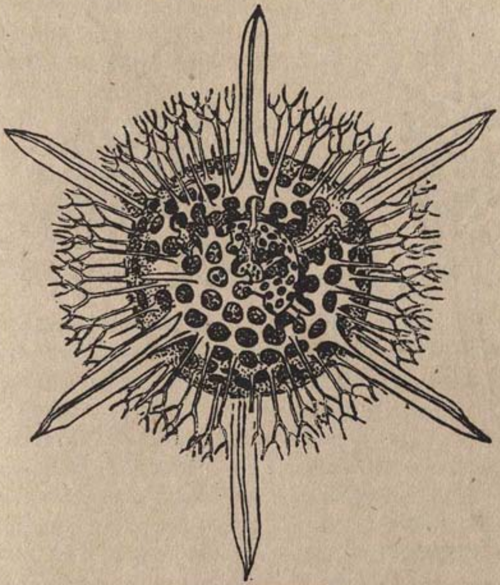


FIG. 3.—Actinomma.

symmetry of their skeletons, they are called Radiolarians; their tiny skeletons, formed of hard silica, now make up thick beds of cherty rock. Unfortunately, the details of the skeletons are usually obscured, except in relatively modern rocks.

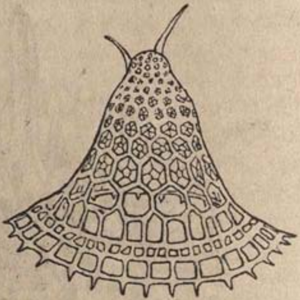


FIG. 5.—Clathrocyclas.

FIG. 4.—Lithomespflus.

LAND FORMATION IN BRITAIN; END OF THE ORDOVICIAN.

Throughout this age, there were times when first one part and then another would become land, only to be submerged again. After the deposit of the radiolarian chert, however, a more permanent change to land conditions set in, and for a long time most of Britain was again high and dry. It would be about this period that the little pencil-line fossils, referred to above, began a vertical transition which has now landed them on the top of Snowdon (Plate 32, A).

But Nature is very slow in her work, and seemingly capricious. She no sooner makes a land than she destroys it; she no sooner hollows out an ocean bed, than she must perforce turn it into land. So it was with our country at this time. For we now enter on another marine depression, which later became of world-wide magnitude.

A word here upon names. The name of the period from the Cambrian to the land creation just referred to is *Ordovician;* that from the Ordovician to the end of the age is called *Silurian:* both are derived from the names of ancient Welsh tribes. The distinction between these ages has been found to hold good all over the world.

The Great Silurian Coral Seas.

In unfortunate Britain, the second half of the age was like the first—brown with mud. Elsewhere, however, the gradual disappearance of what lands there were, combined with the slowing down of volcanic activity, made the sea clear and blue. Many forms of lime-secreting animals sprang into existence; and from the turbid waters of a volcanic shore we are transported, as if by magic, into the fairy wilderness of a coral isle. A sort of universal ocean gradually came in, which, submerging first one tract and then another, ended in later Silurian times by covering practically the whole of the northern hemisphere. As in the Cambrian, however, the subsidence and accompanying deposition was much greater in north-western Europe than in the Baltic; for beds which in Gothland are but 208 feet thick, and contain all the distinctive fossils of each part of the Silurian, are found in Wales with 75 times that thickness. It was as if the sea-floor were a hinged door, opening downwards under what now forms Wales and the Irish Sea, whilst the hinge remained practically stationary in the Baltic lowlands. A striking illustration of this fact is shown by the horizontal attitude of these rocks in Esthonia, Livonia and the Ladoga region. Far away across the Russian plains, however, was another "door"; for in the Ural Mountains the Silurian rocks are both thick and strongly folded.

Remnants of the Land.

Such land as was left in the northern half of the Old World probably formed a chain of islands, running from Central France, by way of Bavaria, to Russia. These formed an incomplete natural barrier between the great northern ocean that covered Britain, Germany, the Netherlands and part of France, and an even greater sheet of water, which included in its swollen lap the Mediterranean, the south of France, the Alps, Bohemia, Spain and Portugal. Out of this waste of waters projected, at long intervals, meagre remnants of the ancient lands—island indicators of what they once had been, like the pennies received in change from a sovereign.

Both branches of this great ocean had extensions, along routes which are not conclusively known, to the site of the Himalaya; and their extensive tides rolled resistlessly across the seas covering Siberia and China to the Pacific. The wide, arid deserts, the snowy ranges and deep gorges of that most picturesque part of Asia, had no existence then, or for ages afterwards. Farther south, the continent of Gondwanaland was now become merely an archipelago of islands, large and small. Burma, the Shan States, northern India and bits of the Indies, were sooner or later eaten out of it by the ever-advancing sea.

Gaspé Peninsula.

If the reader's eye, wearied first with mud and then with water, be turned upon the New World, it will afford him but scant relief. The interior Appalachian Sea, to which I have already referred, extended its bounds, and the broad channel that now skirts the rugged wastes of Gaspé and the more genial shore of New Brunswick, lost most of its southern boundary.

Hereabouts, during this subsidence, no less than 7,000 feet of limestone was laid down: one of the thickest piles of rocks of that age in North America. The limestone is largely made up of the remains of corals, both single individuals and massive colonies, together with the newly-created sea-lilies or crinoids, with sea-mats, seaweeds, pencil-line fossils, trilobites and many others, countless in number, buried one upon another for generation after generation and century after century. All had been called into existence by a long spell of quiet conditions, with warm waters and, presumably, abundant food. A sudden shock was, however, given to the inhabitants of this peaceful sea, by an abrupt and very severe outbreak of volcanic activity, which eventually wiped them out and closed the age (70). It is a curious circumstance, worthy of remark, that geological records repeatedly show long-continued subsidence to be followed by a severe volcanic outbreak, tempting one to adduce the first as the cause of the second. Probably, the strain of the depression sets up stresses which are relieved by cracks; and these afford vents for the omnipresent molten matter beneath the crust.

Warm Waters in the Arctic.

In addition to the Appalachian Sea, most of the old Laurentian land fronting Hudson's Bay was submerged; and places which are now the haunt of the musk-ox and the Eskimo were then the warm waters of a coralline sea. Not only the Canadian Archipelago, but Greenland, and also Spitzbergen, one the coldest and the other the most miserable spot on the face of the globe, enjoyed a genial climate; so much so that the warm ocean possibly extended across the Pole itself. As we progress, we shall learn to regard this anomaly as the normal state of things and the conditions of to-day as those which are abnormal: the sheets of ice which at present render those large tracts of the Earth's surface untenable, seem to have had no permanent place in the past, and it is highly possible that they will disappear in the future.

SOUTH AMERICA IN THIS AGE.

The other half of the New World, in Silurian and Ordovician times, is not well known. There was a sea in the Western Argentine; and right along the west coast may have stretched a knobby line of heights, the first Cordillera, but considerably to the west of the modern Andes. It is interesting to note that the ubiquitous pencil-line fossils have got themselves built up into the heart of the continent, being found in the valley of the Inambari, among the headwaters of the Amazon (71).

LENGTH OF THE SILURIAN; TREMENDOUS EARTH MOVEMENTS.

Silurian times, the Age of Lime, were not so extensive, perhaps, as their predecessor, the Age of Mud; nevertheless, a million years' duration is the least that can be assigned to them. They ended with a curious reversal to continental conditions, to which the next chapter will be devoted. This is the place to mention one striking dislocation to which the great depression of the sea-bed in north-west Europe seems to have given rise: a thrusting and folding force, acting from east to west, and affecting Western Scandinavia and all Scotland to a most remarkable extent. Earth movements of a major nature are invariably staged in a region where deep ocean fronts high land, or where the vertical relief of the Earth's crust is at a maximum; and they always seem to act from the lower region towards the higher. Thus it was in late Silurian times in north-west Europe. Rocks of all ages, but particularly the Silurian mudstones and limestones, were contorted like so much putty, and thrust up into mountains of which nothing but the roots remain. Such a mass comprises nearly the whole of the lonely, treeless moors of southern Scotland (Plate 32, B). Farther north, in the Highlands, huge and extraordinary dislocations accompanied or followed these folding movements, due, apparently, to the different resistances afforded by hard and soft layers of strata : similar puckerings took place in Norway. Of a surety, however, these movements were both deep-seated, slow and scarcely perceptible, except, perhaps, by earthquakes of greater or lesser violence from time to time. The older rocks were attacked at their weakest point—to wit, the junction between the white Cambrian rocks and the red Torridon Sandstone, with the result that both, but particularly the Cambrian, were driven westwards over the ancient surface of the Lewisian Gneiss, in some places as much as 10 miles from their anchorage (Plate 23, A). How very deep-seated the movements were, is shown by the fact that the gneiss itself was involved in them ; for it, and the Torridon Sandstone with it, was inverted, transported upside down, and dumped on top of the Cambrian. This instance of the reversal of the true order of things is a celebrated one among geologists, who fought it out over that stretch of land for half a century before arriving at the truth. It is interesting to reflect that quite possibly such a movement is even now in progress somewhere deep down in the Earth, of which we, pursuing our daily avocations, are sublimely ignorant.

In addition to the thrusts of broken rock masses, much worse smashing took place along a north-south line which covers most of the Eastern Highlands, and extends in places almost to the Atlantic. There, rocks of all kinds got into a zone of crumpling, and were disintegrated like rotten granite between the fingers : so great was the strain that individual crystals and grains of sand were stretched until they became well-nigh unrecognisable. Thus, a foliated structure was induced, and all these rocks became schists : from their type locality in Sutherland, they are called Moine Schists (Plate 36).

Great Abundance of Life.

Despite these disturbances, and the much older ones of the Ordovician, this age was extraordinarily favourable to marine organisms. In no division of life is this more evident than in the case of the brachiopods and molluscs, of which there were countless numbers. The shallower floors of earthy limestone, also, nourished vast forests of seaweed. We know this, not only directly, from unaltered remains, but also, on a far greater scale, indirectly, through the evidence that these groups of organisms have left behind them in the form of petroleum. Let us digress for a moment to consider this point a little more closely.

The Origin of Petroleum.

It is accepted as a fact by most geologists that petroleum—which comprehensive word must be stretched to include not only thin, or paraffin oils, but also thick and viscous oils, even though their consistence is that of asphalte—derives its origin from the preservation of the fatty parts of marine and estuarine animals and plants. On their decease, the organisms sank to the sea bottom, where, being protected by the water from rapid decomposition, their nitrogenous parts were eaten away by certain forms of bacteria, and the fatty residues buried under the next layer of mud or slime. This went on intermittently for such long periods that thick beds of mudstone or shale accumulated, locking up in their midst the fatty parts of countless generations of sea-shells, weeds and microscopic plants, and (in ages later than the Silurian) of fishes. The combined effect of heat (caused by the depth to which the rocks were eventually buried) and pressure (due to earth movements folding the rocks) extracted globules of oil from the remains;

and these globules, which acted in every respect like water globules under hydrostatic pressure, had a natural tendency to escape into rocks where their movements would be less confined —*i.e.* those with a relatively large grain or pore space, such as sandstones. The direction of movement was generally upwards, until the oil reached such a level—*e.g.* a thick bed of impervious clay—that it could go no farther, when it became trapped. Its natural tendency then was to creep along laterally, filling all the pores in the sandstone or limestone, and gradually extending its area until such a time as the pressure downwards balanced that which had forced the oil up, when it became stationary. Such an area is known as an oil pool; and it is by drilling down to and tapping it, in the same way as one taps artesian water, that we get at our crude or unrefined petroleum; but in the case of oil, there must be much pressure before it will "flow." In some cases, the oil has had but little opportunity of migrating, and has therefore saturated the shales in which it originated; to extract it, the shales have to be mined, and the oil distilled therefrom. By these means it is that Man the opportunist drives his battleships and his motor-cars on the residue of shell-fish and plants that lay on the ocean bottom millions of years ago. As it was not until Ordovician and Silurian times that sufficient of these remains accumulated to make enough oil to be exploitable, it seems a legitimate inference that there was then a rapid increase, not only in the *kinds*, but also in the *amount* of life.

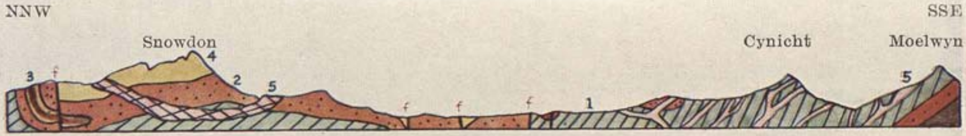
That life, however, was by no means confined to shells and plants. At first, it differed but slightly from that of Cambrian times; but afterwards, newer and newer forms were introduced, and whole groups came into being before the close of the Silurian which almost certainly had no existence in the Cambrian. Thus, vegetation got a firm foothold on dry land at last; whilst a new and greater terror was added to the sea, in the shape of the earliest shark-like fish.

The Bed of the Silurian Sea.

We must not conceive the floor of this watery world as flat. On the contrary, it was—in some localities at least—altogether the reverse. For instance, in some of the interior United States, the sea-bed was diversified by the existence of large numbers of steep-sided mounds or reef-knolls. These originally formed, perhaps, around some nucleus of coral growth and shell remains; growing, by the slow shovelling up of lime and other detritus by the currents, into large and curious tombs having a strong external similarity to coral reefs. They are found fossil, just as nature buried them; and their exact mode of origin has been a matter of acute controversy. In other places, long slopes, varying from a few degrees to as much as twenty degrees from the horizontal, were covered with mud or sand, according to their nearness to the land; and in yet others, submarine volcanoes, with their conical heads *below* the surface, spluttered up poisonous fumes and occasional showers of ashes into the midst of the alarmed denizens of the deep.

Silurian Crustaceans.

The Trilobites, at the beginning of this epoch, were still predominant, in many and varied forms, including giants some 2 feet long. However, their enemies, the lobster-like Pterygotus and other Eurypterids, were rapidly developing into formidable foes. Some of them, before the close of the Silurian, had outgrown by four times the largest of the trilobites, and were consequently larger than any animal yet created. These monsters had four eyes, two of which were only larval, and six pairs of legs—the first pair developed into powerful nipping claws, and the last pair into strong swimming feet, armed with spines. With such appendages, not to mention

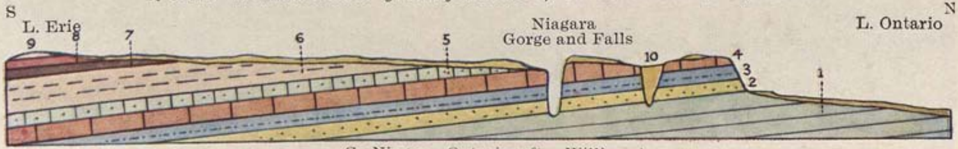


A : Snowdon and Moelwyn, North Wales (after Ramsay).

1 Llandeilo & Bala beds. 2. Lava. 3-4. Ashes, etc. 5. Greenstone dykes.

B : Southern Uplands of Scotland, near Garvald (after Peach and Horne).

1. Chert. 2. Glenkiln Shale. 3. Hartfell Shale. 4. Old Red Sandstone. f.f. Faults.



C: Niagara, Ontario (after Williams).

1. Ordovician. 2. Medina. 3. Clinton. 4, 5. Niagara. 6 Guelph. 7. Cayugan. 8, 9. Devonian. 10. Pleistocene. f.f. Faults.

Pl. 32. **Sections through Ordovician and Silurian Rocks.** *H* 104.

Pl. 33.

H 105.

Niagara Falls.

The cliff is an escarpment of Silurian age, traceable for hundreds of miles. (See also p. 304).

their massive tails, they undoubtedly presented an awe-inspiring aspect to their smaller brethren, some of whom never outgrew a few inches (Plate 38, 7). Their eggs, berry-like bodies, have been found in great numbers in the deposits of the succeeding age, though they are very uncommon in this.

Descending from the sublime to the ridiculous, we find existing at the same time immense numbers of minute crustaceans (ostracods) of the size and general outline of a small bean; the entire body being enclosed in the skin of the bean, and only the legs and feelers protruding. These little creatures, which preyed on still smaller life, were themselves doubtless a delicacy to many larger and stronger forms: hence, possibly, their self-abnegation in their shells. Another common type of crustacean was the phyllopod, an animal whose carapace or head-shield protected the head and thorax, but left the body naked. The phyllopods were usually only a few inches in length; but exceptionally, giants attained to a length of some 2 feet (Ceratiocaris) One or two primitive scorpions also made their appearance late in Silurian times.

GRAPTOLITES.

The creatures most typical of the age, however, were the Graptolites (Plate 31, *1–4, 10*). Except for a slight development in the latest Cambrian years, they came in with it, and they perished with it. Being, on account of their structure, easily preserved as fossils, they form a most valuable guide to the age of the rocks which entomb them, and which in Britain consist, for the better part, of a very samely mass of shales and slates, altogether nearly 20,000 feet in thickness. The Graptolites, then, must have had an existence during approximately two millions of years. In so long a time they, of course, varied much; and certain parts of the rocks are characterised by particular kinds of Graptolites, by the aid of which, for purposes of study, they have been divided into vertical zones.

The Graptolites belong to the kingdom of animals known as the Cœlenterates, or Hollow-Bowels, the main characteristic of which is that each animal is shaped like the finger of a glove with the end pushed inwards, the food being taken in and ejected from the same opening. The nearest modern analogue of the Graptolites is the common Hydra of our lakes and ponds; hence they fall within the subdivision known as Hydrozoa, a name derived from the fabled Hydra that produced two heads for every one that was cut off; one characteristic of the group being that if cut into two, each half grows into a new animal. The Graptolites formed colonies of these polyps, arranged one above another on a long pipe-like horny home. Each little hydrozoan lived in a tiny cup-like chamber of its own, that budded out from and a little above its neighbour; and from its mouth tentacles stretched, "fishing," so to speak, for its food. The stalk which held the colony, though hollow, was supported by a solid rod or axis: these stalks were variously shaped—straight, branching, spiral, tuning-forked, and so on. Freely swimming about in the open waters, the Graptolites were the great *voyageurs* of the age, and encircled the globe. Many species, however, were more or less stationary, the end of their "string" being attached to a float, or else to a mass of seaweed.

Earliest Corals.

Another great group of animals, the Corals, also came into existence, so far as known, in this age: before its close, they were already exceedingly abundant, in divers curious and often most beautiful forms. Of their origin, we necessarily know nothing beyond what researches into the larval forms of living corals can show us; but it is believed, from analogy, that the fundamental ancestor of the corals was a polyp allied to the hydra (72). Their structure is essentially that of a sea anemone —*i.e.* a cup-shaped body, cemented at the base to some immovable object, or very slightly capable of locomotion; across the inside of the body numerous radially-disposed walls of matter pass, either not quite reaching the centre, or else coalescing there to form a central column. These plates are called septa, and sometimes they grow right through the body-wall, so as to form ridges on the outside of the cup. One cannot say how the ancient corals acquired their hard parts; but it is interesting to note that the modern Madrepores do so in the following manner. After the animal is attached, and has acquired its tentacles, calcareous matter is formed as a secretion on the outer side of the body-wall. At first, a delicate circular basal plate arises; then the radial ridges or septa make their appearance, and fuse together on reaching the centre as described above; while by their outward growth, the peripheral parts also become fused with one another; and the cup is complete. The eggs of corals are fertilised whilst within the septa, and after a varying degree of development are cast out of the parent's mouth, whence they drift away to start a separate existence (73). But corals also reproduce their kind in divers other ways. One of the most curious is reproduction by fission, the animal splitting first at the mouth, and then progressively towards the base, and each half growing into a new coral; or the coral may split transversely; or even draw in its basal part, leaving a torn fragment behind, this fragment growing up into a new animal. As already stated, the Hydroids possess a like tenacity of life. The corals that reproduce by budding are the reef-makers: a bud, which develops into a new polyp, springing out from the side or the mouth of the parent; in the latter case, of course, the parent is killed, but its skeleton remains.

True reef-building corals, so prevalent to-day, were very doubtfully present in that remote age. Considerable rock masses were formed, however, out of bundles of tubular forms; the best-known of which are the Honeycomb Coral (Favosites) and the Chain Coral (Halysites) (Plate 38, *10*). The former's abode strongly simulated a honeycomb in appearance; each little five- or six-sided tube being divided by plates into a number of chambers, like floors of a house. There were also many single corals, of a shape like a small conical cap or a distorted baker's horn (Plate 31, *7*). All the forms were, apparently, as particular at that time in their mode of life as they are to-day; for their skeletons are only found in the clear-water or calcareous deposits, and hardly ever in the mudstones.

SPONGES AND STARFISH.

Sponges were exceedingly numerous, in many wonderful guises. Starfish, also, though always comparatively rare as fossils, were relatively numerous in Silurian times; some being ancestors of the present Sun-Stars, others of the Brittle-Stars (Plate 38, *6*). Various other Echinoderms (urchin-skinned or pimpled animals) shared the bottom with them; and there were doubtless various forms of the delicate and lovely anemone, which, on account of their soft structure, have left no trace behind them.

EXQUISITE SEA LILIES, OR CRINOIDS.

Another animal which must have made a subaqueous paradise of parts of the Silurian seas, was the Sea Lily, or Crinoid. These are not plants, but animals (echinoderms), in which the body is fixed, sometimes throughout life, by a more or less flexible stalk, to the sea bottom (Plate 31, *8*). They have a distinct cup-shaped body, provided with nerves, blood vessels and a digestive system: from the body are given off a number of long, jointed, tubular arms. The latter carry a large number of small side branches, or fingers, from which, through innumerable pores, small hairs or cilia draw in the water and the animal's food to its mouth, which is concealed from view. Some of the ancient forms were permanently fixed to the sea bottom; others groped slowly about from one sheltered nook to another; a few may have drifted at the mercy of the currents, attached to some floating object in an inverted position. Their relatively massive armour rendered them immune from most forms of attack, and was, besides, the means of their preservation through all the changes of succeeding epochs. This armour is a striking instance of the diversity of nature. It comprises a skeleton of carbonate of lime, secreted by the animal in the form of small plates; so many such plates are there in a modern crinoid of ordinary size, that they number 2½ *millions:* and this is in the external skeleton alone (74)!

All the above forms—sea urchins, starfish and crinoids—form a major division of the animal kingdom: the echinoderms, or urchin-skinned. With one exception, they are not found fossil in the Cambrian or older rocks, and we must therefore presume that they came into existence in the age now under discussion. They are the jewels of the sea. This is due, very largely, to their exquisite radial and very generally five-sided arrangement, which gives them the symmetry of an artist's sketch. The ancestors of the echinoderms were undoubtedly stalked forms, living attached to the sea floor or to other objects (75); for it is the influence of a fixed mode of life which has given them their radial structure. Beyond this, their origin is obscure, though there are some relationships with the segmented worms in larval forms of echinoderm. The order of appearance of these animals is also not definitely known, but the crinoids may be the oldest.

During one of the mud-free intervals in the Welsh Marches, a narrow band of limestone accumulated on the sea floor there; this, the Wenlock Limestone, contains a great profusion of Sea Lilies—countless fragments of broken cups, stems and arms, besides many shells, corals, polyzoa, and the like.

SILURIAN WORMS AND BARNACLES.

Marine worms were numerous in this age. Although their frail bodies have perished, they have left us myriads of small horny jaws and teeth (Conodonts, Plate 41, *1–3*). Others, such as Serpula, dwelt in indestructible tubes, encrusting dead shells, together with which they were eventually buried in the mud. Sometimes the miniature baker's horns of the ancient Serpula attained relatively gigantic proportions, measuring 3 or 4 inches in length.

The occurrence of encrusting organisms like tube-building worms and polyzoa at this early date is significant, for it shows that even then the sea was crowded, and the larvae, drifted hither and thither by the currents, settled indiscriminately upon anything which would afford them anchorage.

A form of Silurian Barnacle is known; many ages, however, were destined to elapse ere its descendants could attach themselves to ships!

SEA MATS AND SEA MOSSES.

These most beautiful organisms were extraordinarily prolific. They not only occur abundantly in the limy bands of Silurian and Ordovician rock, but they even make up entire layers of rock—notably in the wall of Niagara gorge.

Despite their seaweed-like appearance, Polyzoa (many animals), or as they are alternatively known, Bryozoa (moss animals), are colonies of minute polypites, each living in a box or cell of its own, but in a common skeleton. So early in their evolution, they already displayed hundreds of different kinds.

One of the best-known, the pretty Lace Coral (Fenestella), built up a fan-shaped calcareous framework (Plate 38, *2*). Others gathered into rods, ornamented bars, or rose in long flexible tufts and branches from a root that was firmly attached to some foreign object; or overspread weeds or shells. They are all very diminutive in size, but often exquisitely beautiful under the microscope (Plate 38, *1–5*).

Molluscs and Lamp-shells.

Lamp-shells were now at their maximum of development, new and larger genera arising with far greater rapidity than in Cambrian times.

Among the molluscs of the time, were some which represented a larval condition of modern sea snails. Both single and bivalve molluscs were infinitely more numerous and varied than in the Cambrian; but the time of their greatness had not yet dawned. Of the Cephalopods, over a thousand different species have been described from Bohemia alone; a striking example, both of the duration of the epoch and of the relative rapidity with which new species can be formed. It is interesting to note that the long straight shells of the Cambrian period were now becoming coiled into flat spirals, with edges closely appressed; later still in the Earth's history, we shall find them changed again, opening into the semblance of a bangle that has been broken and flattened (Plate 58).

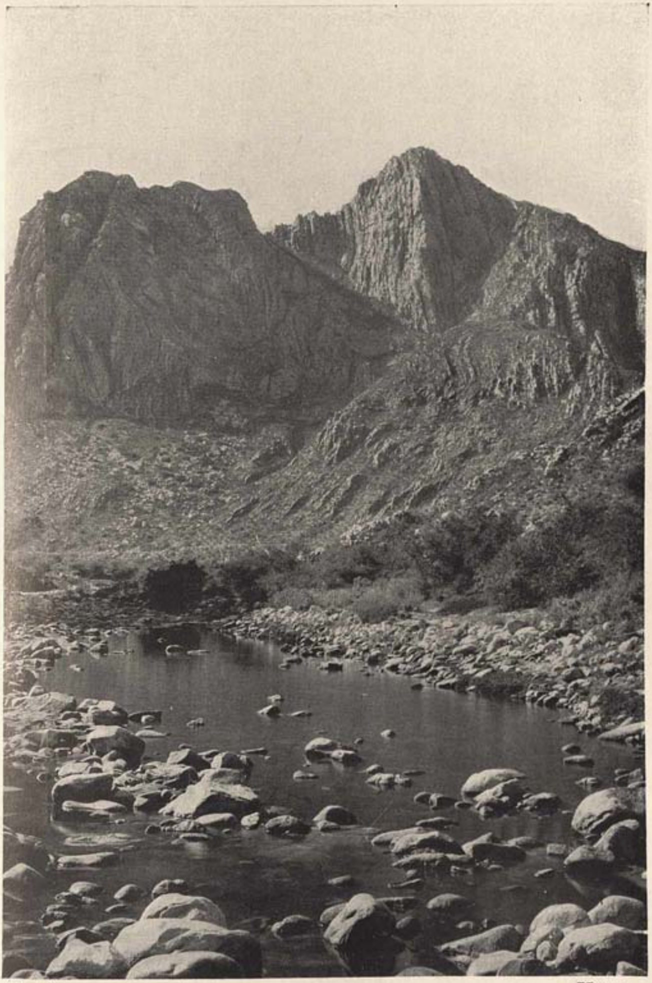
The Earliest Fishes.

Last among marine organisms, we come to the first strange forms of that ever strange and mysterious kingdom, the Fish. The origin of fishes, like that of the other great natural divisions of organised beings, is still a matter of discussion, although it has been determined with a certain amount of probability. Now, a fish stands in the same relation to man or to the apes as does a tiny bit of protoplasm to the complicated octopus, in that it is the earliest form of one of the two major divisions of animal life. They are the oldest creatures whose structure contains, and is dependent upon, a backbone or vertebral column ; and we can get a sort of progression through fishes with a bony backbone, to others with "bones" that are half cartilage, and to yet others in which the "bone" is a mere chord of cartilage alone. The most primitive fish-like creature at present in existence is the Lancelet (Amphioxus), a small semi-transparent animal some 2 inches long, which has no distinct head or tail, and only a chord in place of vertebra. It lives in shallow seas, often burrowing in the sand, its food being minute marine animals. It is allied, on the one hand, with fishes, and on the other with tunicates, which are the highest invertebrates. It has hardly any skeleton at all, and the little that it has is not bone, but cartilage. Now, most modern fishes are bony-skeletoned ; but there still remain one or two representatives of a type which was formerly exceedingly common, in which the skeleton was either all cartilage and no bone, or partly one, partly the other. It is with the latter that we make our first acquaintance, late in Silurian times.

The oldest remains attributed to fish are minute tooth-like bodies (conodonts), somewhat resembling the teeth of modern lampreys and hag-fish (Plate 41, *1–3*) ; but recent opinion inclines to the belief that most of these are really the teeth and jaws of marine worms. The lamprey is another transitional form between a fish and an invertebrate. It has no lower jaw, and thus has to take in its food by a kind of sucking process ; and this is one feature of the oldest undoubted fishes that have yet been discovered.

Besides conodonts, very ancient spines, believed to belong to shark-like fishes, have been found in the Ordovician rocks of Colorado.

Putting all hypothetical forms on one side, there are five varieties in the earliest fish remains. These have been found

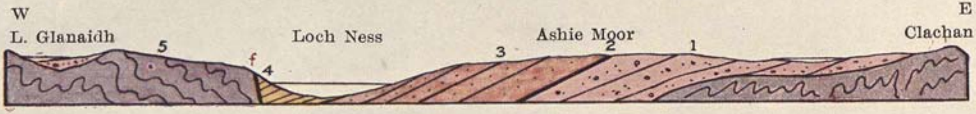


Pl. 34. *H* 112.

Kogman's Kloof, South Africa (p. 23).

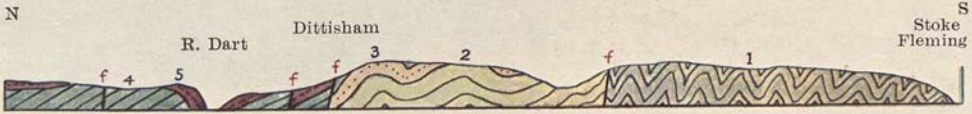
Showin; contorted Silurian rocks.

(Photo. S.A. Govt. Rlys., Publicity Dept.)



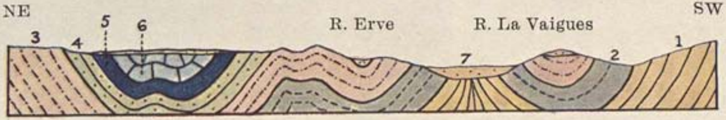
A : Near Inverness, Scotland (after Horne).

1-4, Old Red Sandstone. (2. Fish Bed). 5. Moine Schists. f. Fault.



B · River Dart, South Devon (after Ussher).

1. Dartmouth Slates. 2. Meadfoot Beds. etc. 3. Staddon Grits. 4. Eifel Slate. 5. Limestone. f.f. Faults.



C : On Mans-Angers Railway, France.

1. Silurian. 2-4. Devonian. 5, 6. Carboniferous. 7. Pliocene and Later.

Pl. 35. *H* 113.

Sections through Devonian Rocks.

in Germany, in England and in America, but in very small numbers. It is an extraordinary fact that this meagre fauna occurs in the latest Silurian rocks; yet in the early part of the Devonian, the next age, fish of many kinds abounded. We must conclude from this that their eggs were laid in great numbers; that the continental conditions which succeeded the Silurian oceans were exceptionally favourable to fish development, and that the new order possessed unusual facilities for variations of type.

The Silurian fish were protected by large, angular and often thick scales, jointed together like armour, and not overlapping as the scales of more modern fishes do. These scales or plates were brilliantly enamelled; hence their name of *ganoid* plates. Hence, also, the name of Ganoid Fishes which is applied to the whole family. The lamprey-like form to which we have referred above was one of the most common; it is called Cephalaspis, and its mouth was probably soft and adapted for suction. Its head, on the other hand, was protected by a thick and formidable shield, composed of ganoid plates (Plate 41, *4*, *5*). There was also a fish (Thelodus) of shark-like aspect, which may have been furnished with plate-like crushing teeth for grinding down small molluscs and crustaceans; this seems to have been an ancestor of the modern Port Jackson Shark (Plate 41, *6*, *7*). From this time onwards sharks have endured through all the ages; their mobility preserving them, whereas the more solid, grotesque, and armour-plated fishes of the Devonian, by their own inaptitude for change, speedily brought about their own extinction.

THE EARLIEST PLANTS.

It is in the Silurian, also, that we are able, for the first time, absolutely to identify terrestrial remains; for in its upper part occur the oldest known traces of land plants. Singularly enough, the remains exhibit a considerable variety, and are far from being the lowliest of plants; so that they must have had ancestors of which traces have not yet been discovered. These gaps must be disconcerting to the tyro in science; but when it is remembered that geology is still exceedingly young; that a large part of the Earth's surface has only been superficially examined; that a still larger part has not been examined at all; that even close examination is highly dependent upon suitable exposures of the rocks; and finally, that it is more or less chance which guides us to the tombs of the dead organisms: we see that it is our ignorance which causes the gaps, and not Nature. The Silurian plants include ferns, of more than one species; lycopods, or club-mosses; and a form (Psilophyton) intermediate between the two. They were all non-flowering plants, and doubtless beautified the islands of that time but little; nevertheless, we may be certain that their shade was grateful and their nutritious parts beneficial, to the animals which, first in strange, larval forms, and afterwards in kinds for ever growing in beauty and complexity, developed, stage by stage, in those ancient lands.

CHAPTER V.

The Age of Fishes (*Devonian and Old Red Sandstone*).

THE GENIUS OF HUGH MILLER.

WHATEVER merits or demerits the study of the Stone Book may possess, it has, at least, the saving grace of forcing a man to use his eyes and his brain; common operations, more or less incidental to the human species, but singularly neglected by a large proportion of men. Yet they may be practised, to the advantage of humanity, anywhere, at any time, by rich or poor alike: a fact that has been signally illustrated by the history of Hugh Miller, the celebrated author of "The Old Red Sandstone." This man was a humble fisherman's son. He was no good at school, and he attained, unwillingly, and very early in life, the arduous post of workman in a stone quarry. By his industry, his intelligent observations and his singularly graphic powers of describing just what he saw in simple and rational English, this humble Scotchman outstripped in success many a better-trained geologist; and his work on the Devonian rocks of his own country has long been recognised as a model of its kind. The period with which this chapter deals is the period of Hugh Miller; one cannot think of the one without recalling the other.

GREAT CHANGE FROM THE SILURIAN.

As the Silurian, with its vast oceans and scattered islets, its submarine forests and its humid climate, its newly founded groups of animals and plants, was a complete reversal of preceding conditions, so was the Devonian, to a marked extent, a reversal of the Silurian. The change, however, came gradually. In various parts of the world, the Silurian sea bottoms were upraised to form land; then cut into by streams, and slowly worn down again; whilst in other parts the sea grew so shallow that large embayments were practically cut off, and converted into immense, desolate lagoons, choked with weeds and slime. These, in turn, through the accumulation of river-borne detritus and the sweetening influence of river waters, became either very slightly brackish or altogether fresh. These lakes existed, at or near sea-level, for an extraordinarily long time; so long, indeed, that adjacent lands were raised above the sea, carved into hill and dale, and then into lowlands, and re-submerged, during their continuance. This was not, however, the condition everywhere. There were areas which entered the period as deep or clear water, and continued as such practically throughout the epoch; and in these localities limestone accumulated on a grand scale.

This twofold character runs through the whole of the Devonian record; and to it is due the apparent lack of connection between the red sandstones which accumulated in the lake basins, and the almost pure limestones of the open ocean, with their totally different fossil remains, which was long a puzzle to geologists. The former rocks owe their name to their prevalent colour (though many of them are yellow), and to the fact that there exists a much younger series of red sandstones, distinguished for convenience as the "New Red."

Old Red Sandstone Lakes in South Wales.

If we fix our attention firstly, as hitherto, upon our own country, we find, in the west, an example of the dual relations just referred to. All over South Wales the Silurian sea grew shallower and shallower, and long mud flats formed over an area of many hundreds of square miles, pushing back the ocean waters to the south and south-west. To the north, in what is now the middle of Wales, a land mass arose, apparently to a considerable height; this stretched from the heart of England across the Irish Sea through the centre of Ireland, westwards for an unknown distance (Plates 39, 40). The waters south of it deepened over the North Devon coast; but south of that again there was either land or an area where sediments failed to drift. There was thus in that region a greatly enlarged Bristol Channel, but very much deeper, and probably bordered by mud flats on all its shores; herein new and strange kinds of molluscs grew, while farther out the Sea Lilies flourished on a scale hitherto unknown. Far to the north and east of the marshes that covered the South Wales shore stretched a large lake or lakes; and in these unfavourable waters the marine shellfish grew stunted and wizened; the fish proper, more easily adaptable, undergoing extraordinary changes which will be illustrated later. It is quite likely that, imitating the modern lamprey, the development of these fish in fresh waters arose through marine forms going up the rivers to spawn. This area affords, at the present time, a particularly striking change from the ancient conditions; for the beds of these same marshes and lakes now form the summits of the highest hills in the district, including the great mass of the Brecknock Beacons.

Volcanoes in Devonshire.

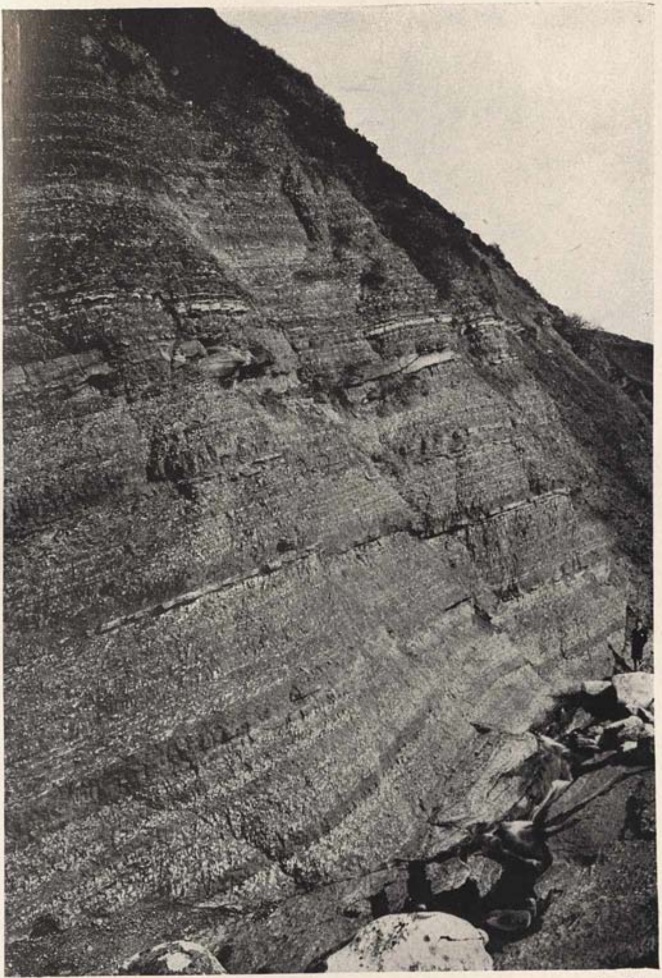
At a considerably later date, the southern part of Devonshire subsided into a limy sea-bed; but in the neighbourhood of Totnes volcanic fissures opened, and built up a group of small cones (Plate 35, B): at this time these must have stood as islands well out to sea. Towards Land's End the sea was probably much shallower, but it certainly covered the bulk of Cornwall.

At a still later stage, North Devon formed the lip of the marine basin once more, possibly by the southward growth of the South Wales marshlands; and land plants from the east and north were washed out to sea in considerable numbers.

It is in Devonian times that we find the oldest records at present known of the world's metropolis. During parts of that age, the site of London was covered by marine waters of no great depth; the old sea-bed lying 1,066 feet beneath the surface at Meux's Brewery (76). At about the same depth under West London sandy beds contain Devonian fishes.

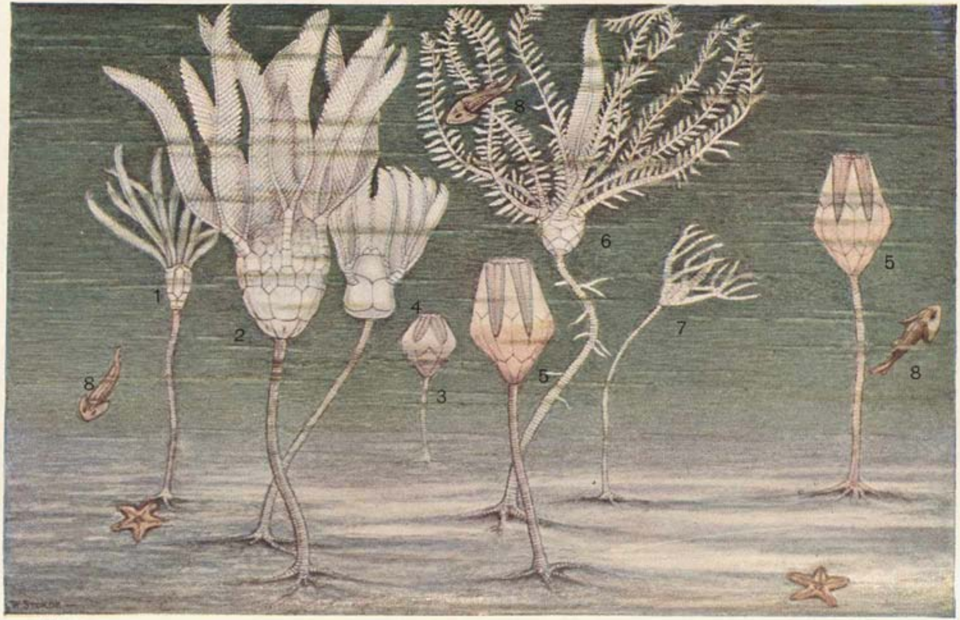
THE SCOTTISH OLD RED SANDSTONE LAKES.

During all these changes, the great lakes in which the Old Red Sandstone was accumulating underwent many vicissitudes, the exact nature of which is by no means clearly written in the Stone Book. In addition to the lake which covered South Wales, and which probably extended across the southern border of Ireland, at least as far as Dingle Bay, there was another lake on the northern side of the central land mass already referred to: this lake covered most of south-central Scotland and northern Ireland. Yet another lake or lakes stretched across the site of the Grampians and the moorlands of Sutherland and Caithness to Orkney and Shetland; its western shores a little east of the storm-swept Scottish west coast, and its waters reaching far to the east across a North Sea that was every whit as shallow as the present one, well into Scandinavia (Plate 35, A). Here, again, we have striking differences between old and modern times; for the bottoms of the old lakes are now built into the unscalable precipices that front the Pentland Firth and the North Sea. It must be understood that the Silurian islands which had previously occupied much of the lake sites were not suddenly submerged. Rather was the invasion quiet and insidious, first one place and then another succumbing to the slow onward creep of the water.



Pl. 36. / 118.

Cliff of Moine Schists, Scotland (p. 102).



Pl. 37. I 119.

Carboniferous Sea Lillies (p. 137).

1. Dichocrinus. 2. Actinocrinus. 3, 5. Pentremites. 4. Platycrinus. 6. Æsiocrinus. 7. Poteriocrinus. 8. Cephalaspis.

Some islands of Silurian rock persisted, in fact, until long after the first formation of the lakes; but sooner or later, landmark after landmark disappeared; bays crept in, around and behind the dunes; narrower and narrower grew the ribbons of disappearing land; islands were formed, and from them islets; until at last nothing but the chill ripple of a featureless watery plain remained.

Cheviot Hills still Active Volcanoes.

At about this time, the Cheviots exhibited much activity in the unfamiliar guise of volcanoes; and in place of the windswept heather-clad moors that now confront us, we must conceive as existing there a line of cinder cones, possibly of great height, which were more or less constantly active. The prevailing winds were apparently strong; for the ashes from eruptions were blown far and wide over the lakes, into which they sank in immense quantities.

Climate of the Old Red Sandstone.

These winds were possibly also cold, though conveying hot materials. Sir A. C. Ramsay has suggested, from the existence of many stones bearing marks similar to those made by ice, that the region was snow-clad as well as firebound, and that icebergs may have floated upon the placid waters (77); but his conclusions have by no means been generally accepted. It is, in fact, very difficult to see how, in that event, the warm-water life forms which crowded the neighbouring seas could possibly have survived; for the snowline must have been near lake level for the bergs to float, and the lake levels were almost certainly not far above that of the sea. In other words, the general temperature must have been abnormally low; as to which we have no other evidence than the scratched stones.

These, also, are a doubtful guide at best, since very similar marks are made by wind in hot desert regions.

On the whole, I incline to the general view, *i.e.* that the Old Red Sandstone lands were hot and dry. This contention is supported by the fact that at times the lakes drained or evaporated away, only to return later in greater force than ever. Large parts of the deposits, also, are composed of coarse, angular fragments; such beds, like the Torridon Sandstone, may owe their origin to cloudbursts in a desert region. The rivers apparently passed through a relatively barren territory, where iron was readily dissolvable; for on entering the lakes the waters were heavily charged with carbonate of iron, which, on being deposited, formed a thin film around each grain of sand, and so gave the latter its predominant colour. The presence of many species of fishes, however, shows that the lakes could not have been excessively salt.

Gap in the Record; Thickness of the Old Red Sandstone.

At length we arrive at one of the worst gaps in the Stone Book, a whole page having been torn out. Apparently all the lakes died away, leaving the region for a long while as a dry land. Then occurred a partial renewal of the old conditions, with a certain amount of interruption due to inroads of the sea; and a totally new series of lake deposits was laid down over the first. This endured for a further very vast time; until, in fine, the gradual sinking of all the areas permitted full ingress to the sea, and there was formed, first muddy limestone, and then pure limestone. These alterations imply that the land had receded far and wide: at this point, which marks the beginning of the Coal Age, we must pause.

The total thickness of the Old Red Sandstone is "at least 15,000 or 20,000 feet" (78). At our standard rate of deposition, this would represent some two millions of years, but in reality it was probably much less, because there is no relation between rivers filling up a lake basin and the ordinary deposition of matter upon a sea floor.

IMMENSE LIMY SEAS IN THE RHINELAND.

Elsewhere in Europe, the same contrasts between the blue-white sea-bed and the brick-red lake bottom prevailed. The basins of the lower Rhine and the Meuse formed a clear sea for the greater part of the age, in which were deposited some 18,000 feet of rock, largely limestone: a record of length equal to that of the Old Red Sandstone, when measured by averages, but in reality very much longer. At times the monotony of this seascape was varied by *Incidents*. Thus, in the Eifel, for a considerable while, a group of small oceanic volcanoes, similar to those of Devonshire, belched out a truly prodigious quantity of ashes. At one period, also, the Rhenish sea was covered with coral reefs on the most lavish scale, which grew from small and insignificant scattered islets into imposing masses. Sea lilies also abounded in those favoured waters. The waving of their innumerable arms may be likened to the trees of a submarine forest bending beneath each gentle tide or current (Plate 37). The reefs doubtless grew rapidly; but the energy of the busy workers was of no avail against the immutable laws of nature. Destruction overtook them in due course, just as it had overtaken all their predecessors; and in their place newer and yet newer forms lived and died.

THE DEVONIAN IN EUROPE GENERALLY; THE WORLD-WIDE SUBMERGENCE.

The Straits of Dover apparently formed dry land at the beginning of the Devonian, although to the west and south-west, in Normandy, a wide bay of the sea extended. Later on, this crept to the north, and blotted out the land entirely.

The Pyrenees had a similar history to the Rhine. There were also volcanoes there, whose ashy ejections buried many colonies of the beautiful Sea Mosses. The Pyrenean sea originally stretched across much of Léon and Asturias; but later in the age those areas were islands in it.

In the Hartz Mountains, in Nassau and in Westphalia, the same general tale may be told. Farther north and east, however, the conditions in central Russia roughly paralleled those of South Wales. The vast plains of north-west Europe were gradually converted into areas of marshland, beside which the modern Pripet Marshes are insignificant. These marshes became repeatedly, through some slight general subsidence, a shallow sea floor, only again to grow into marshes and lakes; so that in this region the Old Red Sandstone and marine Devonian records are, as it were, interleaved. Where the land lay which supplied the immense mass of rock required to form the Russian beds is by no means clear, but it was presumably to the north and south; for the Ural Mountains and the lands east of them were at that time an area of relatively deep water—a coral-strewn sea, which probably extended across the site even of the Snowy Altai, communicating by broad channels with the Pacific. Burma and Indo-China were other sea-beds of this age; and in its later stages a great transgression of the ocean buried most of China in addition. In Southern Asia, also, there was for a long while water, nothing but water. The mighty Hindu Kush, the savage gorges of Afghanistan, the barren salt deserts of Eastern Persia, the cold and lonely Pamirs, and the colder and lonelier Tian Shan, were all deep below one common ocean. Only in the peninsular portion of India is the eye mentally relieved by the sight of land. Even Africa, hard and dour though its fight had been against destruction, had to participate to a minor extent in the submergence;

a small area in the south succumbed, and a vast area in the Sahara went to make up an already over-swollen Mediterranean. The last great expedition of Captain Scott brought back Devonian fishes from the Antarctic. Australia tells us the same wet tale. Salt water rolled over much of Queensland, New South Wales and Victoria. But as the age wore on, tropical vegetation developed in the shoreline marshes that bounded this last sea—to such an extent, indeed, that its remains, pressed down beneath the muds amongst which they grew, consolidated to form some of the oldest known beds of coal.

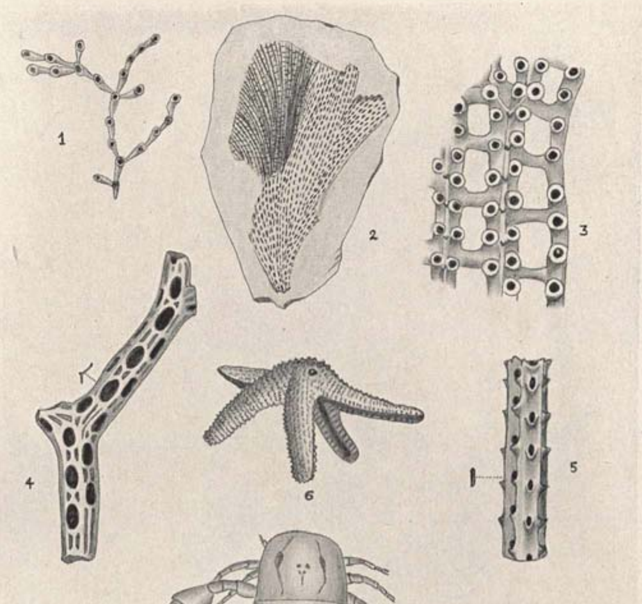
Reversal to Terrestrial Conditions.

One would imagine that such an universal transgression could have no purpose but the utter destruction of all land surfaces; but with the apparent inconsistency which is so characteristic of inscrutable Nature, much of this ocean became land again before the Devonian closed, especially in Asia. Despite its vicissitudes, in fact, the anomalous result was the formation of much land at the expense of the sea; and this was the inauguration of the great continents that characterised the Coal Age.

Running down the centre of the Atlantic, there is believed to have been created a practically unbroken land barrier at this time. Of its nature we know nothing; but its existence has been deduced as essential to an understanding of the distribution of life during the Devonian. To the west of this barrier, in the northern hemisphere, was sea again, and then a land roughly coinciding with the present eastern United States; and beyond that, lay the great interior sea of North America, which had persisted unbroken since Cambrian times. To the north of this, the old continental mass of Labrador and Canada still maintained its head above the waters; but those grim shores were now festooned with ferns and moss-like plants; and the occasional hum of an insect provided a welcome change from their former barren stillness.

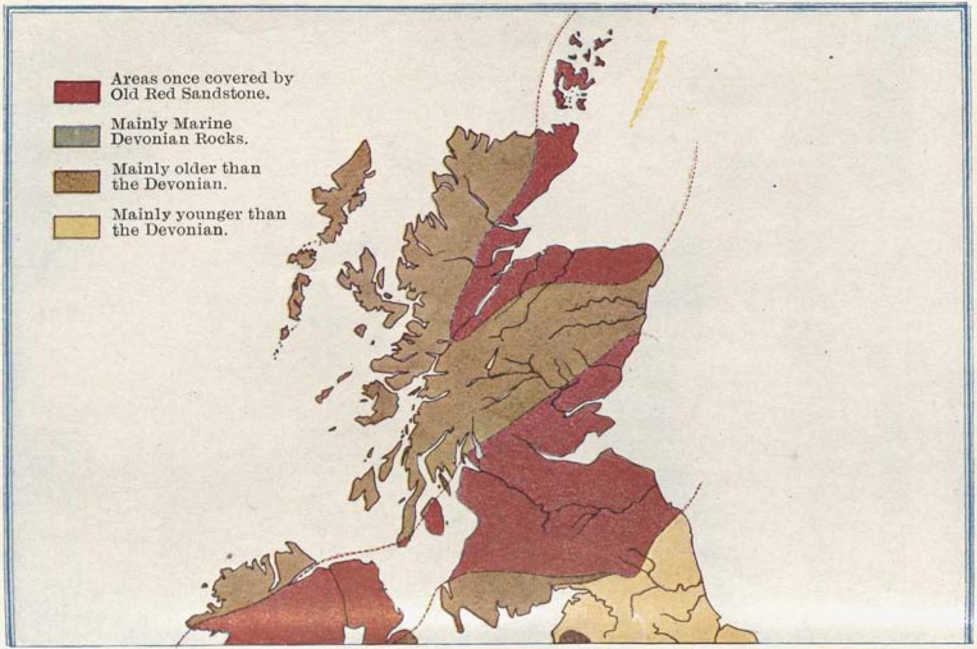
Seas in the Heart of North America.

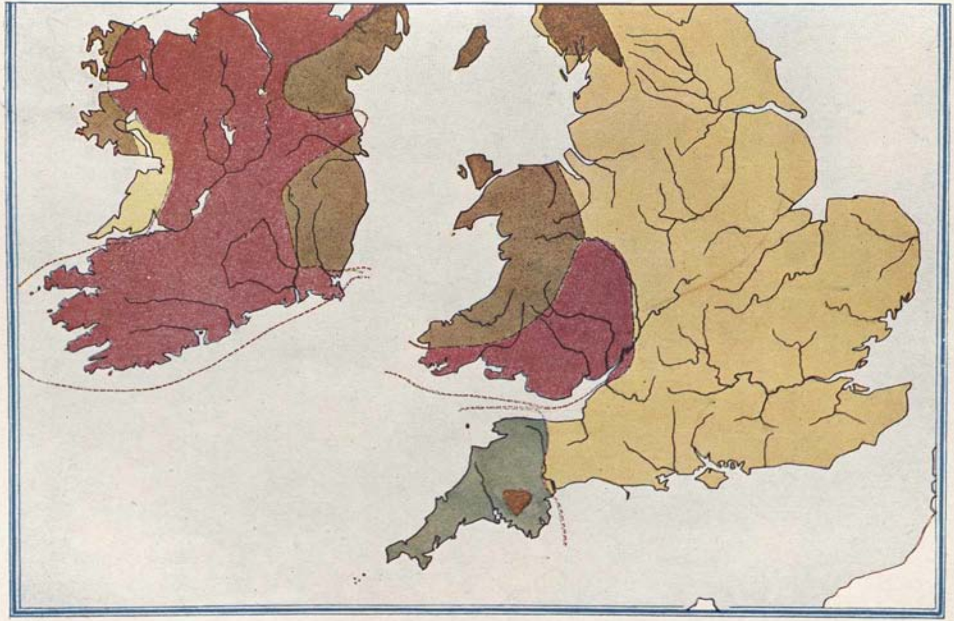
In the interior or Appalachian Sea, with its northern extensions over Ontario, the animal life could ill communicate with that in the oceans outside the mountain ring. It developed, therefore, along somewhat different lines, providing us with a whole host of new forms—a noteworthy instance of the effect of environment on natural changes. This interior sea was not one regular water-mass, like, for instance, the Gulf of Mexico; but was divided by islands of greater or lesser extent into more or less definite parts. The most important of these was the Appalachian Sea proper, which lay over the site of the Appalachian Mountains. This had on its eastern shore, in the New England States, a high land at least 10,000 to 15,000 feet high, which had ramifications from New Brunswick as far south as to Tennessee; its western shore was bordered by much lower lands, with clear, placid streams meandering idly through the meadows. The highlands terminated on the north in the Gaspé Peninsula; but one part of this large promontory was still deep water, just as it had been in Silurian times. Hereabouts lay the channel between the Appalachian Sea and the Atlantic; it was originally both broad and deep, but later it shallowed considerably, and at last formed a huge morass, bordering the rivers which flowed from the west. By this time gigantic tree-like club mosses dotted the land; and we can legitimately imagine that all the waterways were choked with weeds, and that in their devious channels strange and curious fish floundered about in the mud. In the marshy deposits many remains have been found, all of which foretell the close approach of the luxuriant vegetation of the Coal Age.



Pl. 38. *I* 124.

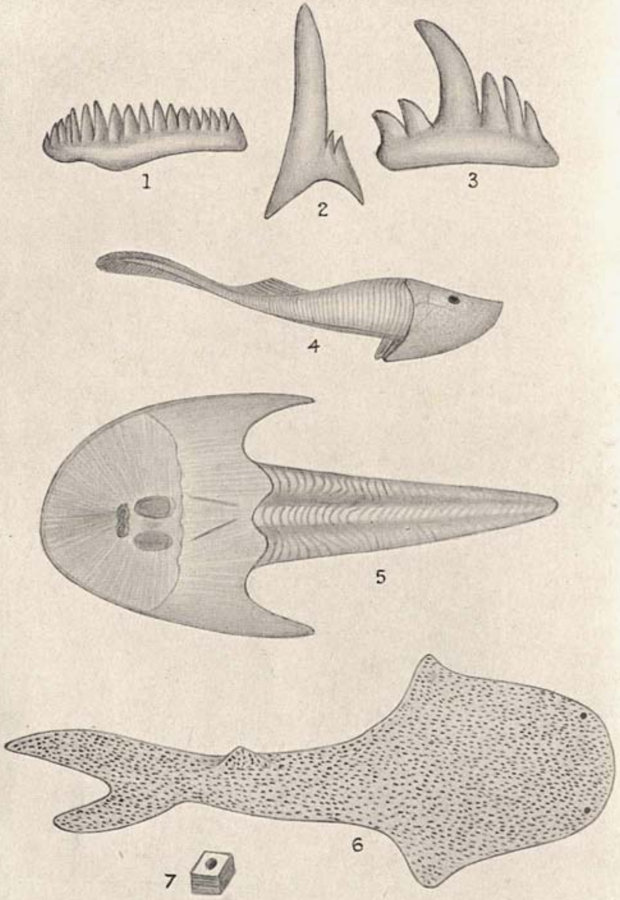
Silurian Life Types. 1. Stomatopora (×4). 2, 3. Fenestella (nat. size & ×12). 4. Nematopora (× 12). 5. Arthroclema (× 12). 6. Palæaster. 7. Eurypterus. 8. Rhynchonella. 9. Lituites. 10. Halysites.


Areas once covered by Old Red Sandstone.
Mainly Marine Devonian Rocks.
Mainly older than the Devonian.
Mainly younger than the Devonian.



Fls. 39 40.

Approximate Map of the British Old Red Sandstone Lakes.



Pl. 41. *I* 125.

The oldest known Fishes (pp. 112-113).

1 3. Conodonts (after Newberry). 4, 5. Cephalaspis. 6, 7. Thelodus and scale (after Traquair).

The region to the north of Canada still enjoyed a climate as genial, apparently, as that of the Silurian. Much of the Archipelago was deep clear sea, with corals and sea lilies in abundance; it shallowed, however, on approaching the west coast of Greenland, where rivers built up estuarine beds, and fish remains have been found.

There was another almost isolated sea in Dakota; another in part of the Yukon basin; yet another in the Bighorn district of Alberta; and so on. In the Kasaan Peninsula, in Alaska, an area of shallow water bordered numerous volcanic islands; while in other parts of the gold-seeker's paradise mountain movements were at work, to the accompaniment of numerous earthquakes and eruptions of lava. Before the end of the Devonian, however, all underwent the fate of the rest of the land, and were submerged.

Steady Development of Life.

When we come to examine the life of the Devonian and the Old Red Sandstone, we have primarily to note its dual character. For the first time in our story, we are dealing with land deposits on a large scale, in times when life was well developed; and we consequently expect to find, and actually do find, a wealth of new beings.

The slow and gradual development of marine organisms, of which we have outlined a few striking types, pursued its grand course without intermission. As our narrative proceeds, however, these simpler forms must be crowded out more and more, by newer and higher creatures; so that we are forced to dismiss them, despite their interest, with a few brief words.

Great Variety of Invertebrates (Plate 43).

Of the Sponges, which were again very numerous, the most curious, perhaps, were the singular glass-rope sponges, which lived in the deep sea, anchored on the bottom by long tufts of rooting spicules. Sea anemones, lace corals, jellyfish and their kind abounded, in new and more highly developed forms, along with a steadily dwindling percentage of those from the Silurian. Of the reef-building corals, which now began to be prominent, Favosites was still one of the commonest kinds. Large banks and reefs were also formed by Stromatopores. These were colonies of Hydrozoans, whose existence began by the encrusting of some small foreign body such as a shell; and from this humble beginning the animals grew into really gigantic proportions. Another type of Hydrozoan, the Graptolites, failed to survive the Silurian. When we recall their extraordinary abundance in that age, and their total absence from the next, which in its oceanic phases was apparently identical, we cannot but marvel at the sudden and utter destruction of this great group of animals. That something injurious, either in the ingredients of the sea water, or in the form of minute parasites, prevented their eggs from maturing, is obvious: what it was, is a question as yet unanswered.

Echinoderms in general, and the exquisite sea lilies in particular, also tenanted every limy sea (Plate 37); but their maximum development had yet to come. A great variety of molluscs and seaweeds, also, littered the bottom, and peopled nearly every pool. The lamp-shells had passed their maximum; the trilobites were rapidly on the down grade (Plate 43).

So the great pageant of Nature goes on. The old order dies, but a new order comes to take its place. Change, and ever more change, has been the keynote of biology throughout the ages; and always that change is towards a higher being. In the Archæan, we found seaweeds; in the Cambrian, trilobites; in the Ordovician, Graptolites; in the Silurian, Corals; in the Devonian, many plants and fish. As we proceed, we shall pass on up the scale of organised existence;

and when we have come to the end, and enumerated man, we cannot help asking, " What will come next ? "

DEVONIAN PLANTS.

Turning to the Devonian land areas, we find that the few plants of the Silurian had developed into an abundant and varied flora. There were several cone-bearing (coniferous) trees, mostly ancestors of the Araucarian Pine. No doubt these peopled grassy, well-drained slopes, and may have been some distance away from the great marshes. Of the other vegetation of the uplands, we know practically nothing. It is hardly ever found fossil; for such forms usually have to be drifted down to some estuary or flood plain to ensure their preservation, and are, as a rule, destroyed in transit. Of the low, wet places, on the other hand, quite a great deal is known. The vales and river banks were peopled by a large variety of ferns, some of them very little different from the ferns of to-day. There were also, in sufficiently humid and mild places, a fair number of large tree ferns, also numerous club mosses that formed trees 20 to 30 feet high: we shall have occasion to speak more particularly of these in the next chapter. It is certain, also, that the streams were bordered by divers kinds of reeds; although these plants, owing to the relative ease with which they rot when dead, have left few traces in any age. Grasses, which are a relatively modern product, had at that time no existence. We may also be sure that wherever stagnant waters lay brooding in the hot sun, there would coats of green scum hide their surface; but the beautiful water lily, the cry of the bird in the bushes, and the hum of the bee around the flowers, were just as certainly absent. All water surfaces near shores, also, most probably abounded in very minute but exquisitely designed plants, called plankton, whose nature makes their detection as fossils well-nigh impossible.

But the most curious plant which clothed the Devonian lands was undoubtedly a gigantic ancestral horsetail, called Calamites, which grew to a length of 20 feet or more. These plants were

"slender ribbed and jointed externally; and from the joints there proceeded, in some of the species, long, narrow simple branchlets, and in others branches bearing whorls of small branchlets or rudimentary leaves. The stem was hollow, with thin transverse floors . . . at the joints; and it had no true wood or bark, but only a thin external shell of fibres and scalariform vessels. The Calamites grew in dense brakes on the sandy and muddy flats subject to inundation, or perhaps even in the water; and they had the power of budding out from the base of the stem, so as to form clumps of plants, and also of securing their foothold by numerous cord-like roots. . . . The fruit was a long cone or spike" (79).

Lack of Flowers. Insects.

There were no flowers. The vegetation, such as it was, was almost solely green; and except in the cone-bearing trees, true wood was scarce. What tenanted these silent glades? Anything? We cannot say. Except for some scorpions, doubtful grasshoppers, cockroaches and a kind of May-fly (which had wings 5 inches across, and which appears to have been ancestor to quite a number of flies), air-breathing animals were non-existent. The busy hum which enlivens our forest glades; the call of birds from their nests in the reeds; the rustle of animals stealthily winding a serpentine course through the grass; the swarms of flies and mosquitoes which haunt the surfaces of meres—all these things had no existence. It was thus, despite its beauty—for beautiful it must have been, even though flowerless—a silent and forbidding land; an untenanted house, newly furnished.

But although the land was thus, so to speak, empty, the same cannot be said of the water, which, in addition to all the varied life forms we have indicated above, teemed with fish of many different kinds and sizes, from gigantic lobster-like creatures, buried in heavy armour, down to tiny little animals less than an inch in length.

Change of Habits in Eurypterids.

Our old crustacean friends, the Eurypterids (Plate 38, 7), were here, of course; though under a slightly different guise, and somewhat smaller. Having massacred most of the trilobites, they were changing their habitat, and had acquired a taste for shoreline scenery, with its bunches of reeds and its mud-banks and river bars. From this, they gradually proceeded, during the Devonian and the early part of the Coal Age, to acquire a greater and greater liking for fresh water; until at last they became confined to lakes, and died away there.

The Lobster of Balruddery.

A close ally of these creatures was the celebrated Lobster of Balruddery (Seraphim). As this fossil is peculiarly the property of Hugh Miller, it had best be described in his own inimitable words:—

"One of the strangest organisms of the formation is a fossil lobster, of such huge proportions that one of the average-sized lobsters common in our markets might stretch its entire length across the continuous tail-flap in which the creature terminated. . . . The claws nearly resembled those of the common lobster: their outline is similar; there is the same hawkbill curvature outside, and the inner sides of the pincers are armed with similar teeth-like tubercles. The immense shield which covered the upper part of the creature's body is more angular than in the existing varieties, and resembles, both in form and size, one of those lozenge-shaped shields worn by knights of the middle ages on gala days rather for ornament than use. . . . As shown in some of the larger specimens, the length of this gigantic crustacean must have exceeded four feet. Its shelly armour was delicately fretted with the forms of circular or elliptical scales. On all the many plates of which it was composed, we see these described by gracefully waved lines, and rising apparently from under one another, row beyond row. They were, however, as much the mere semblance of scales as those relieved by the sculptor on the corselet of a warrior's effigy on a Gothic tomb—mere sculpturings on the surface of the shell" (80).

It is from the similarity of the markings on these scales to those sculptured on the wings of cherubs that the quarrymen gave the creature its name of Seraphim.

Devonian Fishes: the Winged Fish.

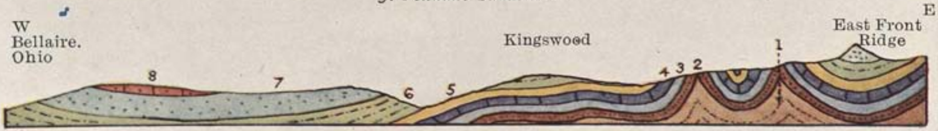
Coming to the true fish, let us first glance at one of the most uncouth and curious creatures that ever bore the name: the Pterichthys, or winged fish (Plate 45, 2). This looked not unlike a monoplane seen from below; though of course it was very much smaller. Its body resembled that of a small turtle, but was thicker; both the upper and lower surfaces were protected by a strong armour of bony plates having a warty or tubercled surface. Its two pectoral fins or paddles were placed so far forward as to give the body a disproportionate and decapitated appearance. "From their form, they cannot have been much use in swimming; but they probably, as suggested by Owen, enabled the animal to shuffle along the sandy bottom of the sea if stranded at low water" (81). The tail was long and angular, and covered with small tubercled plates like scales. The creature was quite small, varying from 1 to 7 inches in length. The wings, with their sharp points and oar-like blades, were mainly weapons of defence, and only erected, apparently, in moments of danger and alarm; normally, they lay at the animal's side, its sole instrument of motion being its tail. The specimens observed by Hugh Miller were almost invariably in this state of alarm, thus indicating that they had come to a

A : Dysart Coalfield, Fife (after Geikie).

1. Carboniferous Limestone. 2. Millstone Grit. 3. Coal Measures. 4. Red beds. c. Coal Seams.

B : South Wales Coalfield (after Hull).

1 Old Red Sandstone. 2. Carboniferous Limestone. 3. Millstone Grit. 4, 6. Lower and Upper Coal Measures. 5. Pennant Sandstones.

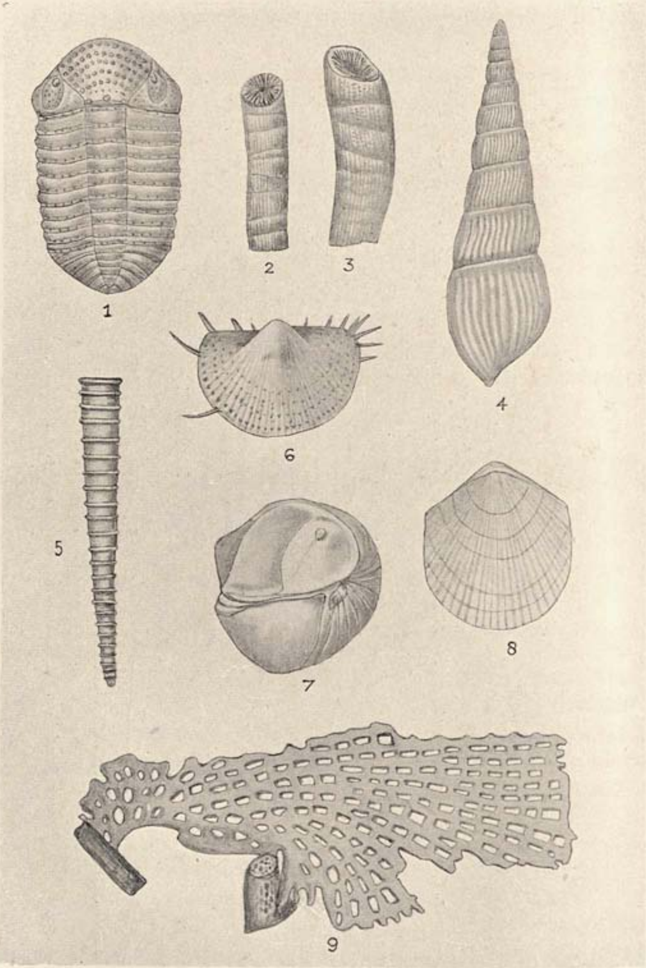


C : Appalachian Coalfield (after White).

1.2. Devonian. 3. Pocono Sandstone. 4. Mountain Limestone. 5. Millstone Grit. 6, 7. Coal Measures. 8. Permian. f.f. Faults.

Pl. 42. *l* 130.

Sections through Coalfields.



Pl. 43. *f* 131.

Devonian Life Types. 1. Phacops; 2, 3. Cyathophyllum. 4. Loxonema. 5. Tentaculites. 6. Productella. 7. Homalonotus, coiled. 8. Atrypa. 9. Fenestella.

sudden and violent end. The occurrence is particularly interesting, as it illustrates a phenomenon which has more than once in the world's history caused the extermination of a whole fauna—to wit, the sudden destruction, over an area extending, in this case, at least from Orkney to Cromarty, and covering some 10,000 square miles, of all the fish which dwelt in that sea.

"The platform," says Hugh Miller, "is strewed thick with remains which exhibit unequivocally the marks of violent death. The figures are contorted, contracted, curved; the tail in many instances is bent round to the head; the fins are spread to the full, as in fishes that die in convulsions. . . . The remains, too, appear to have suffered nothing from the after attacks of predaceous fishes; none such seem to have survived. The record is one of destruction at once widely spread and total so far as it extended. There are proofs that whatever may have been the cause of the catastrophe, it must have taken place in a sea unusually still. The scales, when scattered by some slight undulation, are scattered to the distance of only a few inches, and still exhibit their enamel entire, and their peculiar fineness of edge. The spines, even when separated, retain their original needle-like sharpness of point. Rays well-nigh as slender as horsehairs are enclosed unbroken in the mass. Whole ichthyolites occur in which not only all the parts survive but even the expression which the stiff and threatening attitude conveyed when the last struggle was over" (82).

The distinguished geologist conceived that the disaster might possibly have been caused by an eruption of calcined lime from some distant volcano. The perfection in which the remains were found can doubtless be attributed to the preservative action of carbonic acid gas in the mud.

Coccosteus, a Strange Creature.

A fish which, in some respects, resembled Pterichthys, was Coccosteus (Plate 45, *4*). Its body, however, was larger, the paddles much smaller, and the tail long and kite-like. A more vital distinction is that its jaws were placed vertically instead of horizontally; and its teeth, instead of being fixed in sockets or merely placed on the bone, were like the teeth of a saw apparently cut out of the solid. The average length of Coccosteus was about a foot, but it sometimes attained twice that size.

Nakedness of Devonian Fishes: Dinichthys.

Now, modern fishes have the bones covered over with skin or scales; but many of the Devonian fishes were naked in that respect, the bare bones being covered only by a shining layer of enamel. "The enamelled teeth were placed in jaws which presented outside a surface as naked and as finely enamelled as their own. The entire head was covered with enamelled osseous plates, furnished inside, like other bones . . . with their nourishing blood vessels and perhaps their oil" (83). But while all was bone without, all was cartilage within.

Another apparently mud-loving fish, in the same general class as Pterichthys and Coccosteus, was a form, peculiar to North America, known as Dinichthys (Plate 45, *2*). The *head* of this creature sometimes measured as much as 3 feet in length, and was covered by a buckler of ganoid plates similar to that of Coccosteus. It had extraordinary teeth, "which must have been associated with carnivorous and predaceous habits. Thus, in the lower jaw, the extremity of each ramus (or jawbone) is bent upwards and pointed so as to form a huge and sharp tooth on each side; the margins of the mandible beyond these, being enamelled for some distance, form a sharp cutting edge which may be entire or serrated" (84).

The Buckler-Fish.

Cephalaspis (head-buckler, Plate 41, *4*, *5*) was another curious fish, its head shield being shaped like a saddler's knife. Its eyes were close together in the centre of the head, like those of a flatfish; but it had a soft toothless sucker-like mouth, like a lamprey. Its body was covered with enamelled scales. The plates on the head formed a huge buckler, sometimes a third of the length of the body: hence its name. This was one of the hardiest of the Devonian fishes; for it survived not only the great changes from the Silurian to the Devonian, but also the draining of the lake beds between the first and second deposits of Old Red Sandstone. It was apparently estuarine in habit, but later may have become wholly freshwater. It is certain that it frequented marshes and lagoon-like embayments such as formed the South Wales shore in those times.

Nearest Modern Fishes resembling those of the Devonian.

The only modern fishes in any respects resembling the above singular creatures are the sturgeon, the garpike and the Australian mudfish. Many of our modern fishes, in fact, are relatively recent; a fact which makes the sudden development of so many different genera at the beginning of the Devonian more remarkable than ever.

A Giant Fish, Holoptychius.

One of the largest of Devonian fishes was Holoptychius (Plate 45, *5*), which had scales 3 inches long by 2 inches broad, and over ⅛ inch thick. Some of its teeth, too, were more than an inch in diameter. The scales were tubercled or warty and marked with curious furrows; and, to show how endless is the diversity of natural design, "no two scales exactly resemble one another in the minute peculiarities of their sculpture . . . and yet, in general appearance, they are all wonderfully alike" (85). Specimens of this great fish have been found which were 7 or 8 feet long by a third as broad. The armour in which it was encased might have served a crocodile or alligator of five times its size. Its jaws, and probably all its real bones, were naked and enamelled. "A row of thickly-set pointed teeth ran along the japanned edges of the mouth—what in fish of the ordinary construction would be the lips; and inside this row there was a second and widely-set row of at least twenty times the bulk of the other, and which stood over and beyond it, like spires in a city over rows of lower buildings in front" (86).

We could continue this list of curious and wholly extinct fishes until we wearied the reader of the subject—so many and varied are the forms with which the epoch abounded. We cannot conclude, however, without remarking that, besides the stranger forms, there were considerable numbers of shark-like fish in the more open seas. Owing, perhaps, to most of the remains having been eaten by other animals before they could be buried in the oceanic abysses, these ferocious fish have left us little beyond their characteristic teeth and spines.

CHAPTER VI.

The Coal Age (*Carboniferous*).

Origin of the Name.

The period upon which we are now entering is one of the most important recorded in the Stone Book, and we shall, therefore, treat it at somewhat greater length than the others. The name of the age is rather anomalous. It was originally called Carboniferous, because it includes the very valuable coalfields of Great Britain; and from a misconception, due to ignorance, it was at first applied to nearly all coalfield deposits; but for many years, geologists have known that equally great deposits of coaly matter exist in immeasurably younger rocks, bearing totally different names. Furthermore, in the Carboniferous itself, the actual coal occupies only a most insignificant part of the deposits.

Complex Geography of Britain at this Time.

The Devonian epoch closed in a quiet and unostentatious manner. The lakes of the Old Red Sandstone either dried up, or, as is more probable in most cases, were drained away; and by slow degrees the outlines of great continents began to be formed, along the margins of which many and varied forms of plant life seized a foothold.

At the beginning of the new age the arrangement of land and sea was extremely complex, and it is still by no means well understood: Britain, in particular, has not written its part of the story in very legible characters.

The hilly or mountainous ridge that had run in the Devonian across the middle of Wales, towards Ireland on the one hand, and central England on the other, still existed; but from the shore near Haverfordwest the sea deepened rapidly as one went south; and yet, there was almost certainly land again on the North Devon coast. What lay to the east of this estuary or strait is not known; but a tongue of salt water undoubtedly stretched far beyond the site of Bristol into what is now the heart of the country. On the west, this sea was bounded, in the neighbourhood of south-west Ireland generally, and Dingle Bay in particular, by a very rough and rocky coast. Fairly early in the age, the Irish shore was partly worn away and partly depressed below the waters; lagoons were formed, wherein many land plants accumulated; and eventually, a further submergence let in the ocean bodily, flooding all southern and central Ireland, as far north as the Granite Mountains of Donegal.

Meanwhile, the steady uprising of central England and North Wales had given rise to a great extension of our country to the north and north-east; until there was united land, perhaps as far as the Firth of Forth. The Scottish Highlands very possibly had a considerably greater altitude than at present. The climate everywhere seems to have been warm and probably very moist—essentially different from our existing climate in all respects. Pines clothed the hills, and ferns spread in dense green waves upon the lowlands. The rich flora that is preserved in the Coal Measures, including trees 70 feet or more in height, was probably already fully developed.

South Wales a Limestone Manufactory.

But while part of Britain was thus *terra firma*, that large part of it which still remained beneath the waves, was doomed to an indeterminably long period of submergence ere it afforded a soil for the coal to grow upon. The sea-bed of South Wales was constantly undergoing changes: its depth increasing, then shoaling more and more, and then increasing again, time and time again (87). Occasionally, where the docks of Bristol, Swansea and Cardiff now lie, there were numerous lagoons, fringed by corals and tenanted by fish and marine shells: the border of the land being some faint lines far to the north and south. At other times, with increasing depth the sea grew bluer, whilst vast forests of beautiful sea lilies (Plate 37) waved upon its bed; coral reefs arose, hasty and speedily-destroyed structures of lime; and giant armoured fish, the last sad relics of the vast array of the Devonian, lazily swam about. Few or no rivers drained into this sea; consequently, but little mud mixed with the limy ooze that slowly formed on the bottom, from the broken and crushed remains of crinoids, corals and shells. In this way, there was built up hereabouts a vast thickness of limestone—not less than 5,000 feet at its maximum, and perhaps more. During the latter half of its accumulation, the rest of England turned itself into a lime factory; for, first the Midlands, and then the lands of North Wales, the Isle of Man, the site of Dublin and the foundations of the Pennine Chain, succumbed to the waves. Durham and Northumberland, the Lothians, Stirling and Fife, where the water was not so deep, became transformed into a shallow marine estuary, fronting the high northern lands; but at times, even here the water cleared or deepened sufficiently to enable considerable bands of limestone to form. When thus clear, corals and kindred forms of life flourished here; at other times would come a temporary emergence, during which whole forests would arise, only to be later entombed beneath the waters and stored up as coal. To vary the monotony, too, there were occasional showers of ash from some adjacent volcano: precursors, these, of very much greater showers to come.

Strange Aspect of the Country.

No Briton would at this time have recognised his homeland. To begin with, most of it was not land at all, but sea; and half the rest was water too. Then, again, the climate, though not tropical, was much warmer than anything we enjoy (if we can honestly be said to enjoy our climate) at present; and it never varied: assuredly, a great advantage. Summer was much the same as winter; the rainfall was plentiful and constant; and the islands that dotted the country were consequently clad from hilltop to shoreline with dense vegetation. It was as if a small stretch of the subtropical Pacific had been transplanted here, and into it dumped a few lumps of New Zealand. In the shimmering waters, countless myriads of surface animalcules idly sported away their lives; and it is a permissible stretch of the imagination to picture their phosphorescent gleam as aiding the moonbeams in the hush of night. In the shallower parts, corals built up small reefs and knolls; while in the deeper areas single corals led a very isolated existence, surrounded by immense forests of gently waving crinoids, of graceful and fascinating tree-like outline. Between the surface and the bottom, each in its appointed depth, a great and growing number of fishes darted about—ancestors of the sharks and rays, holoptychians, mudfish and many others. Where the shore was not too muddy, an obscure and pitiful little crustacean crawled about: the last of the trilobites (Phillipsia), its only claim to notice, like that of the fledgling lord, is its ancestry.

How deep was the sea? One cannot say, although a limit can be fixed. Limy remains cannot under present conditions be formed in deeper water than 12,000 to 15,000 feet, and in the modern oceans all deposits below that are of red clay. The probable maximum depth over England, however, is not likely to have reached such a figure; yet we may be sure that it was enough to give the water that translucent blue which is the happy mean between the greenish-grey of the North Sea and the blue-black of the Atlantic abysses. There must at different times, of course, have been many variations, both in colour and depth ; and this went on repeatedly, like the regular motions of a machine: deep, semi-deep, shallow, deep, semi-deep, shallow.

Huge Duration of the Limestone Age.

It is also impossible to say, even approximately, how long this state of affairs continued ; but it was an exceedingly great while, for the bottom became choked up with countless remains of dead molluscs, sea lilies, corals and animalcules ; and such detritus cannot possibly have formed rapidly. Compressed as they now are, it appears that a foot thickness of them—representing possibly two or three times that quantity when originally laid down—would require very much more than our standard one hundred years to accumulate ; and we should probably be nearer the truth if we doubled or trebled that time. Very thick beds of the main limestone are composed almost entirely of the stems of crinoids ; there are also thick beds of chert, largely composed of the minute spicules of innumerable dead sponges. Contemporaneously with their interment, in the north of England, very valuable beds of coal were forming, also with extreme slowness. In fact, the Carboniferous Limestone is, with one exception (the Chalk), the greatest graveyard that Nature has to show.

Volcanic Outbreaks.

Although, in general, this was in Britain a period of quiet and tranquil deposition, there were, in places, symptoms that all was not well in the Earth. Thus, in Devonshire, volcanic fires again burst forth, on this occasion north of the old centres; in time, a great volcano came into being, which long persisted (though, in the main, a silent giant), and of which the long, gloomy slopes of Brent Tor are the sole remains.

Even in South Wales the steady deposition of limestone was halted for a time, while an island mass had a temporary existence: some 1,200 feet of limestone may have been worn away before this island disappeared again (88); and at the end of that interval, the age of limestone-forming had ended for ever in that locality.

On the low-lying territory between Fife and Yorkshire, many eruptions of ashes and lava broke out. Linlithgow and the Lothians were studded with numerous small oval orifices, as if the Earth had got a bad rash on its skin. Into the shallow waters crept small streams of lava, and into the Earth itself were injected, from the molten reservoirs below, many sheets of igneous rock. Some of the plugs of hot rock that once filled the orifices of the cinder cones have been preserved to us, their surrounding walls of cinders having been worn away: Bass Rock, Berwick Law, and many of the other hills in that locality, are such roots of volcanoes. Interesting evidence has been obtained to show that the climate during the volcanic episodes was semi-arid, with sudden torrential downpours. These cloudbursts swept away the masses of half-consolidated ash from the sides of the cones, large masses being floated down with the mud to considerable distances from their points of origin (89).

There were also two spells of vulcanism in southern Ireland, probably of submarine origin. In the Limerick district an ash and lava cone was built up; and one of the beds of lava is 150 feet thick.

At about this time, the site of Glasgow was a weedy and mollusc-covered sea-bed, not very deep, but so prolific in life that the oleaginous parts of the remains thoroughly soaked the mud that buried them, and so gave rise to the well-known oil shales of Lanarkshire.

Deposition of the Millstone Grit.

The scene changed. The bed of the deep sea grew shallower and shallower. The masses of sea lilies withdrew further and further afield. The land not only expanded laterally, but also vertically—*i.e.* it grew higher; so that the streams, which had formerly scarce strength enough to carry even mud into the ocean, now began to transport coarse grit, with occasional fragments of plants. The deep marine waters were completely wiped out; and in their stead was substituted a partially enclosed area of shoals, swept by strong currents, and closely confined by the land. In parts of Lancashire, lagoons and marshes, crowded out with Coal Age plants, had a sporadic existence. In the big north-eastern area, the same conditions prevailed; except that the northern land now probably stretched right across the North Sea into Scandinavia. At times, the muddy flats at the vegetation-choked mouths of the creeks in the north were exposed to the sun's hot rays, and rain-storms left their pittings upon the surface; while occasionally, large amphibians, somewhat resembling gigantic newts, left their footprints on the mud as they wandered from one clump of reeds to another. Eventually, this northern shoreline encroached south as far as Yorkshire; thus making a temporary gap in the story of those parts.

This stage in the Coal Age is known as the Millstone Grit, on account of the hard gritstones which were then laid down in the sea. It was not nearly so favourable to marine life as the limestone stage had been; nevertheless, it has left us a moderate number of marine molluscs, together with numerous drifted land plants. A much greater proportion of the Millstone Grit seems to have been swept into the Lancashire area than elsewhere:

for in that county it attains its maximum thickness of 5,500 feet—two or three times as much as was drifted into other localities. It is the great hill maker of Lancashire, Cheshire and the adjacent region; for, being very much harder in certain beds than in others, the former stand out as conspicuous ridges, locally known as "Edges." Many of the high moorland features in the Peak District, including the precipitous back of the Peak itself, are due to its great resistance to weathering.

Beginning of the Coal Measures.

Once more the scene changed. When the Millstone Grit was pouring into Lancashire, it must have been from lands of relatively considerable altitude, with strong, swift streams; but in the course of time, these lands were worn down into the semblance of a great lowlying plain; and in lieu of the grit, the rivers carried seaward only fine sand and mud. A large estuary appears to have gradually formed, and to have extended its limits southwards and westwards, until even the old islands of the Midlands were enclosed by it. In this estuary were numberless rivers and creeks, whose banks (if one can define them as banks, where land and water seem to have had no definite margin) were clad by many kinds of fern that more or less resembled the common bracken of to-day; while at intervals, gigantic horsetails and club mosses gathered in groves of singular beauty, their trunks, clothed in myriads of tiny leaves, rising without a branch sometimes as much as 50 or 60 feet from the ground. Farther out in the mud, reeds and brakes formed well-nigh impenetrable thickets, from amidst which could be heard the croaking of giant toads, newts and frogs; whilst pike-like fish lazily splashed from one stagnant pool to another. The hum of insects—a new sound, assuredly, in those days—vied with the melancholy call of the amphibians; both were varied by an occasional greater noise, as some huge club moss, eaten or rotted away at its base, fell with a crash into the water. A strange scene! Yet those of us who have been fortunate enough to sit in a clearing in some dense tropical forest, will have no difficulty in conjuring it up: it requires but little imagination, in fact, to smell the stench from the mud, as the black water slowly settles over the fallen giant!

Repeated Burial of Vegetable Débris.

As time wore on, this great estuary or delta slowly and irregularly subsided; and the masses of vegetation that littered its mouth were buried under sand and mud, occasionally with great rapidity; but in time there was sure to come a renewal of the shoaling, another creep forward of the delta, another great jungle and marsh growth, and another inundation and burial. Lakes, and cut-offs of fresh water, alternated repeatedly with incursions of the sea. Here in Britain, as in many other parts of the world, this creation and destruction of shoreline marshes was repeated, not once or twice, but *many dozens* of times; and it is quite certain that in no two of them were the features of the land and sea precisely alike. It seems probable that in many of the creeks the tangle of dead vegetable matter, mixed with the river mud, held back the sea water until it had encroached on the surrounding areas; then the dam would burst, and the rushing waters, carrying a heavy load of sand and grit torn up from the bottom, would sweep in like an avalanche, and complete the destruction. In this manner, trees 40 feet or more in height were buried upright; while the foolish insects and amphibians that had lingered under their shade too long, were involved in their ruin, and buried with them.

The great delta apparently covered the whole of central England, all the coalfields of which belong to it. South Wales possibly, and southern Scotland probably, formed separate basins, yet tied by strings of weed-lined shore to the larger one at various times.

FRENCH, BELGIAN, WESTPHALIAN AND KENT COALFIELDS.

Another great area of lagoons, creeks and tidal swamps stretched from northern France through Belgium into Westphalia. It is an interesting fact that this particular "coal manufactory" ran under the site of the English Channel into what are now the fair fields of Kent; where numerous coal seams attest the repeated formation of shoreline swamps.

FORMATION OF COAL.

It is the slow consolidation and carbonising of the immense masses of vegetable matter that grew in these areas, or were drifted into them from time to time, which built up our coal beds. Looked at merely as a matter of time, the conclusions to be drawn from these black lines in the rocks are perfectly astounding. How great a period was occupied merely in the growth and burial of the coal, may be gathered from the following facts.

Now, the best coal is almost pure carbon, and is composed, in the main, of the bark, stems and roots of the trees of the period, with occasional masses of ferns and brakes. Its constitution, of course, varies from place to place, and is, besides, very difficult to decipher, as most of the vegetable structure was destroyed during the process of carbonisation; but the above may be taken to be a very fair average. Recent microscopic studies show that spores also contributed to the mass; but most of the plants were buried *in situ*.

Such of the trees as were not drifted into their present positions (and they were undoubtedly very numerous) grew on islets in the deltas, or on spits of land in the lagoons; and the soils whereon they grew, together with the shells of land snails, crushed millipedes and skeletons of air-breathing animals, are occasionally found buried with them. Numerous other trunks underwent a longer or shorter immersion before burial; doubtless tumbling into the creeks, and lying there as snags, only covered at high tide, and forming ideal obstacles against which other detritus, floating downstream, might be caught and massed. Of the marsh vegetation, on the other hand—the brakes and reeds—very much must have decayed away, leaving no trace of its existence; but a fair proportion of it was involved in the ruin of the greater plants, and compressed with them. Both on the land and in the water, the accumulations of decaying matter reached amazing proportions. They gathered there, generation above generation, until thicknesses of 100 feet or more had accumulated; and it is difficult to understand how such plants as came last could have obtained a foothold; so that we are driven to the conclusion that the later masses did not grow where they are found at all, but were drifted by water on top of the earlier plants. On any other hypothesis, it seems impossible to account for beds of coal which not only cover a very great area, but are 30 feet thick, even though now much compressed; such thick seams, too, are usually divided into a number of thinner seams by thin partings of hardened mud, indicative of submergence. But that vegetation can grow to a very great extent upon other vegetation is strikingly shown in the modern world. Thus, in the foothills of the Rocky Mountains, particularly in Canada, a tangle of fallen trunks, thorny shrubs, ferns and brakes, so encumbers the earth that the ground is nowhere to be seen, and the unhappy traveller has perforce to grope his way along the slippery, moss-covered trunks, thankful if he makes three or four miles' progress in a day. And this is only in a temperate climate: in a dense tropical forest, such as that of southern

New Guinea, the conditions are far worse. It may be remarked, in passing, that although the Coal Age accumulations have been sometimes compared to peat, there is a very material difference between them; peat being very largely made up of moss remains, whereas coal is mostly tree and fern debris. Peat, it is true, is incipient coal; but coal is not necessarily transformed peat.

Long Time necessary for Coal Formation.

Perhaps the best-known single seam of coal in Britain is the famous 30-feet seam of the Derbyshire field. This, when originally deposited, obviously had a very much greater thickness; and even when compressed, by the weight of overlying beds, into the semblance of lignite or brown coal, it may have contained up to 35 per cent. of water, besides numerous gases; and ages of further compression were necessary to reduce it to the fineness and dryness of true coal, the moisture in which may be as little as a fraction of 1 per cent. Consider for a moment the rate of growth of such a mass. It has been estimated that the product of a heavily timbered woodland, when compressed to the specific gravity of coal, would only amount to about ¼ inch per century. On this basis, the 30-feet bed would take 144,000 years to accumulate. Some geologists deny that the rate of accumulation was so slow; and yet it must be obvious that the enormous mass of plants that collected in the Derby seam took an equally enormous time to *grow*, representing, as they do, countless generations of ferns, weeds and trees. A single one of the trees might possibly live for many centuries ere it fell.

The Welsh Coalfield.

Now, in South Wales, where the British coal-bearing rocks have an exceptionally good development (Plate 42, B), they have a maximum thickness of 12,000 feet. The great bulk of this is made up of the shales and sandstones that entomb the coal; but there are 80 important seams of coal, of which 25 are 2 feet thick and thicker. The total thickness of all the seams, great and small, has been estimated by Professor Phillips at 120 feet (91); and on the assumption that they accumulated at the rate of ¼ inch per century, over half a million years were necessary for the existence of the eighty coal-bearing deltas alone; while the sandstones and shales, even on the most moderate assumption, certainly took as long to build. Another fact that points to the great duration of this period, is that by a slight local uplift—*e.g.* in the Forest of Dean and in Northumberland—islands were formed out of some of the coal measures; and on these islands, rivers had time to form beds and to cut channels through the coal (which was then probably only peaty in hardness) before the islands were again submerged, and fresh vegetable matter accumulated on top of them (92).

Scottish and Lancashire Coalfields.

That the Welsh coalfield was no mere local freak is well illustrated by the Lothian coalfield (Plate 42, A), where the beds, though enclosed in a much thinner deposit of shale and sandstone, are believed to total 180 feet in thickness, and to represent 66 distinct deltas (93). Again, in the coalfield of South Lancashire, there are 75 coal beds 1 foot thick and up, and 150 feet of coal in all (94). In Somerset, nearly 100 feet of coal has been found, in 51 beds (95).

Valuable Deposits of Iron Ore.

It is an interesting (and in a commercial sense exceedingly important) fact that, contemporaneously with the formation of the coal, and in the same localities, great quantities of iron ore were deposited from solution. A partial analysis of six of the South Wales beds of iron ore showed that they contained, on an average, 74 per cent. of iron carbonate, or nearly 36 per cent. of the metal (96). It is to this happy association of iron for tools, and fuel to make them with, that England owes much of her prosperity.

ENGLISH COAL BASINS ONCE UNITED.

The remark made above, that the coal formations of England originally formed one basin, may be perplexing at first to those who have only studied coal in its geographical aspect; for there are, of course, numerous clearly separate basins. But the rocks which form the rims, as it were, of the basins are the Carboniferous limestone, and older rocks; and the earth disturbances which elevated them into their present positions were the cause of much coal being eroded away by rain and rivers, and so lost to man. The basins we see are merely the remnants of one vast series of deposits. We shall refer to these earth disturbances again. They were continent-making movements, and they ended the Coal Age in this country. Furthermore, they were largely responsible for the numerous faults which make it so difficult to work any one coal seam continuously for more than a short distance (97).

How did the rest of the world fare during this long time? We will glance at a few areas as briefly as we can; the importance of the subject will excuse us if we become diffuse.

THE COAL AGE IN NOVA SCOTIA AND NEW BRUNSWICK.

Considering, firstly, the continent of North America, we find in Nova Scotia, extending from the head of the Bay of Fundy across to New Brunswick and Cape Breton Island, a great pile of rocks having a somewhat different history from that of their English analogues. The equivalents of the great Limestone Series and the Millstone Grit have maximum thicknesses of 7,000 and 5,700 feet respectively; while the Coal Measures, as evidenced in the celebrated Joggins district at the head of the Bay of Fundy, comprise a further 9,000 feet; thus, the whole forms an imposing mass of 22,000 feet of pages of Coal Age history.

It will be remembered that in this general area, the flora which was so great a feature of the Coal Age had already obtained a firm foothold during the Devonian; and the Carboniferous species mark the gradual growth, development and change of these forms, rather than an accession of totally new ones. When the age began, much of the area formed a large lagoon, the shores of which sloped gently out to the deeper parts, so that at low tide great expanses were uncovered, and rainstorms, sun-cracks and wave-marks left indelible records of wet, heat and sea. Into the lagoon were washed numbers of plants; the only ones that survived this rough transit on any great scale were ferns and their allies. They were all of types which were living contemporaneously in the *warm* lands of Alaska, Bear Island, Spitzbergen and Siberia. At times, the lagoon barrier seems to have been submerged and the whole area depressed, so as to enable limestone to form. At others, the area shallowed, and became so charged with an excess of salt that thick beds of gypsum were deposited; this can ordinarily only happen when the waters of a lake or lagoon evaporate much faster than they are renewed. These facts, combined with the existence of a deep sea well to the east, indicate a continental border, with a hot and occasionally a very dry climate. In the neighbourhood of Cape Breton Island, there was probably for long a land barrier which separated the lagoon area from another that lay north of it; and on the shores of this barrier, thick gravel deposits, afterwards consolidated into conglomerate or puddingstone, were created by the incessant wear and transportation of the waves. Later on, the barrier subsided in turn, giving way to a limy sea, wherein sea lilies, corals and molluscs abounded. After a further considerable time, there followed some heavy earth disturbances, including a severe pressure from the south northwards; whereby the region was raised into moderately high land, and in the usual way worn down again, until great river flood plains and deltas comparable to those of England occupied its site. These were particularly conspicuous south of the Cobequid Hills; whilst to the north of that range the rivers deposited, probably in a freshwater lake, a mass of red and grey grits of approximately the same age as our Millstone Grit. In this lake, enamelled fishes and small crustaceans were fairly plentiful. Frequently, also, trunks and branches of trees which had fallen into the streams were swept into it and buried there. At length, the sea gaining acess to these waters, the area was converted into a large estuary or delta; and for long ages bed after bed of vegetation grew and died, and was buried beneath succeeding generations of plants. The Coal Age finally closed with an uplift in the Cobequid Hills region; the marshes were drained; and a rough and bouldery coast, on to which trunks of dead trees were occasionally cast by the waves, took the place of the quiet inlets of Coal Measures time.

Similarity between American and British Coal Plants.

The coal deposits of this region are sometimes intimately associated with thin, fossil-bearing limestones of marine origin, but more frequently with the sandstones and shales that indicate the near proximity of land. The plants were of the same general character as in Britain and elsewhere—ferns, reeds, great tree ferns (Lepidodendron), equally great club mosses (Sigillaria), etc. In the neighbouring seas shark-like fish abounded; and on the reedy flats the footprints of huge amphibians have at times been found. A single vertebra has also been found, which is believed to belong to the first of the great Saurian (lizard-like) reptiles which were afterwards to attain dimensions at which one hardly knows whether to laugh or be afraid. But as this is the only trace of that animal so far discovered, we shall, for the nonce, disregard it.

Extraordinary Fossil Forests.

One of the many interesting things about this district is its forests of buried trees, which have for three-quarters of a century attracted the attention of scientific men. They were buried vertically, just as they grew, although attaining a height of 40 feet—a sure indication of the rapidity with which the sandstone and mud accumulated about their stripped and blackened trunks. These trees, which are found in numbers, be it understood, and not in isolated fragments, have been discovered at as many as seventeen different levels; and as most of them terminate downwards in beds of coal, there is here the clearest evidence imaginable of so many different forests growing one above another. The trunks themselves form hardened sandstone cores.

In passing, it may be remarked that these fossil forests are by no means confined to Nova Scotia. A long and detailed list of occurrences of tree trunks being buried erect was given by Sir Charles Lyell many years ago, the trees varying up to 72 feet in length. There were, he says,

"in a colliery near Newcastle . . . not less than thirty, some of them 4 or 5 feet in diameter, visible within an area of 50 yards square, the interior being sandstone, and the bark having been converted into coal. . . . Such vertical stems are familiar to our miners under the name of 'coal pipes.' (They) . . . are much dreaded . . . for almost every year in the Bristol, Newcastle and other coalfields, they are the cause of fatal accidents. Each cylindrical cast of a tree, formed of solid sandstone and increasing gradually in size towards the base, and being without branches, has its whole weight thrown downwards, and receives no support from the coating of friable coal which has replaced the bark. As soon, therefore, as the cohesion of this external layer is overcome, the heavy column falls suddenly, in a perpendicular or oblique direction, from the roof of the gallery whence coal has been extracted, wounding or killing the workman who stands below. It is strange to reflect how many thousands of these trees fell originally in their native forests, in obedience to the law of gravity, and how the few which continued to stand erect, obeying, after myriads of ages, the same force, are cast down to immolate their human victims" (98).

The greater security afforded by modern conditions of working has lessened the danger ; but the moral is as applicable as ever.

CENTRAL NORTH AMERICA.

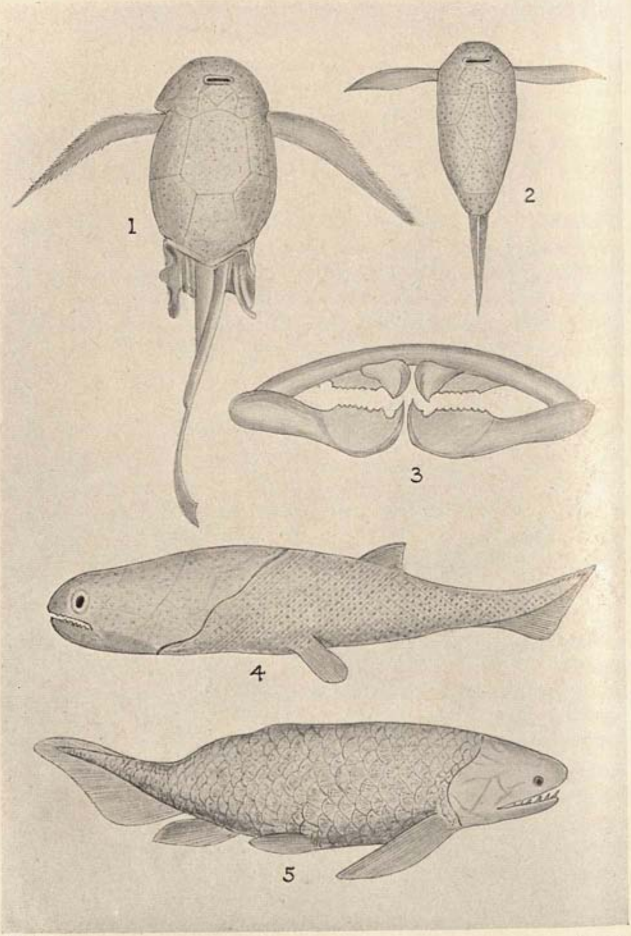
The history of the rest of North America during the Coal Age was long and complex. Essentially, however, all the central and south-central part of the continent was a more or less limy sea, abounding in surface-loving foraminifera (Plate 85), and dotted with many islands the shape and dimensions of which were incessantly varying. The sea alone remained constant. Out of it, first one and then another temporary land arose, only to vanish again when their parts were played. On the eastern side of this interior basin, roughly along a line running down the axis of the Appalachian Mountains, grew great quantities of marsh-loving coal-forming plants ; but these became more and more scarce as one travelled west.

The valuable coalfields of West Virginia, Pennsylvania and Ohio are of this age (Plate 42, C). The coals are, as a whole, older than the coal series of England ; most of them belong to mid-Carboniferous time. Vast marshes extended from far

Pl. 44. *L* 152.

Grand Canyon, Colorado, from Bright Angel Point (p. 154).

The whole of the rocks, from the red bands upwards, are Carboniferous and Permian.



Pl. 45. *L* 153.

Devonian Fish.

1. Bothriolepis. 2. Pterichthys. 3. Dinichthys (Jaws). 4. Coccosteus, 5. Holoptychius.

out to sea right up to the base of the ancient and mountainous lands which had for many ages formed a barrier between the interior sea and the Atlantic. "These marshes . . . were separated from the sea by barriers that, in places at least, were low; for numerous thin beds containing marine fossils are found throughout the coal-bearing formations in close proximity to coal seams, and even, in a few places, in the midst of the seams, showing that there were temporary incursions of sea water" (99).

The later part of the Coal Age in the Middle States showed even more remarkable variations than the first had done. There is a constant change in the nature of the sedimentary beds every 20 feet or less vertically, as well as a rapid alteration from one kind of matter to another in a short distance laterally. The most massive limestone beds are rarely over 40 feet thick, and some of the most persistent bands do not exceed 2 feet in thickness (100).

Changes in the Cordillera.

The general limit of the great Interior American Sea on the west lay in the heart of the present Cordillera: it is difficult to be more precise without some explanation, because the average conception of the Cordillera, due to the reticence of geography books on this region, is a single mass of high mountains, of no great width but of considerable length. As a matter of fact, the Cordillera is some 500 miles wide, and in places much more, At the boundary line between Canada and the United States, it can be divided into no less than seven great elevated tracts, more or less parallel—to wit, the Rocky Mountains, or the Front Range; the Purcell Mountains; the Selkirk Mountains; the Columbia Mountains and the Belt of Interior Plateaus; the Cascade and Coast Ranges; and the Vancouver Range and its southern continuation, the Olympic Mountains or

Washington. These are separated by valleys of greater or less magnitude, from the Rocky Mountain Trench, which is 1,000 miles long, down to narrow gorges between isolated groups of peaks (101). Geologically, this vast region is divided into two very distinct parts, the Selkirk Range and the mountains to the east of it (including, of course, the Rockies) forming one part, and those ranges to the west of the Selkirks forming the other. A part, at least, of the eastern half was below sea-level during the earlier stages of the Coal Age; but later on, a movement of great magnitude below the crust, which seems to have affected all the mountains between Alaska and Utah, brought this half of the Cordillera above sea-level. At the same time, the western half was correspondingly depressed; so that the Carboniferous seas on the east were much older than those on the west of the dividing line. Farther to the south, however, in California, this change-over did not take place till the end of the Coal Age; and deposits of both earlier and later Coal Age time were laid down on the site of the mighty Sierra Nevada. Hereabouts in the sea were a number of lines of volcanic weakness, and eruptions occurred intermittently throughout the epoch. Farther to the south still, New Mexico was the coastal part of a land of moderate size and height. (*See also* Plate 44.)

In the western half of the Cordillera, particularly during the later stages of the epoch, almost continuous volcanic activity prevailed. A great series of rocks some 9,500 feet thick (the Cache Creek Series), comprising limestones, muds and the ejecta of volcanoes, was here laid down in sea water, in what is now the rain-sodden, deeply-trenched and forest-covered region of British Columbia. Enormous numbers of a large foraminifer called Fusulina (Plate 85, *9*) flourished in these waters. It was a spindle-shaped representative of the Nummulites, or coin-fossils, and reached a length of over half an inch; although most of the foraminifera are microscopic objects. There were, besides, numerous islands composed of dead and living corals; besides the familiar smoking cones of the volcanoes, their sides stained red on a background of black, doubtless ending at the base in a circle of green vegetation; and outside that would be the white sand of the beach and the long blue rollers of the Pacific. This pleasing prospect was enhanced in the north by an extensive land that covered the Yukon region, along whose wide plains great rivers slowly wound for an interminable time. The contrast between this northern district of low relief, with its warm, humid climate, its semi-tropical ferns and its general air of a green paradise, and the present-day barren deserts of gravel-strewn valleys bordered by steep hills whereon even the soil, creeping down like an ill-fitting skin, will not lie still, is a grim one, and not at all in favour of the existing state of things. Considerable lakes existed in some parts, in which the streams built great deltas; these latter are sometimes as much as 4,000 feet thick. The volcanoes, which crowded the southern side of the land, thinned away to the north; and in the Canning River Region of North Alaska the only evidence of them is a few minor flows of lava, laid down on an old sea floor. So far north as this, even, corals and sea mosses abounded (102).

Singular Conditions North of Canada.

In what are now the snow-capped northern islands of Ellesmere Land, North Devon and Heiberg Island, the Coal Age rocks bear the clearest possible evidence of warm and genial climates; and a volcano spouted noisily forth from the last-named place, not at all in the manner of Erebus, but with an environment like that of Mont Pelée: its pumice mingling with and killing the creatures that covered the sea floor (103).

WARMTH AND VEGETATION IN ANTARCTICA.

Jumping, by a stroke of the pen, to the opposite end of the Earth, we find that about this time Adélie Land, Antarctica, was also a region of warm and plant-bearing waters, most probably fresh and marsh-like in character. The plants have consolidated into coaly shales, and their exact age is not yet known; but probability places it at about the end of the Carboniferous. The reed-covered and fern-strewn marshes came to a rude and sudden end here, apparently; being buried beneath a huge sheet or sheets of lava, 600 feet in thickness.

DEVELOPMENT OF CONTINENTS IN SOUTHERN HEMISPHERE: AN ICE AGE.

In the southern hemisphere as a whole, there was, towards the close of this epoch, very much more land than at present; and a continuous tract extended from Eastern Australia across the site of the East Indies to the western borders of Hindostan. This was the north-east edge of a continent known as Gondwana-land, which harboured for ages certain species of plants; the finding of the latter in many widely separated localities has enabled rough lines to be drawn across areas where nothing but ocean now exists, but which may then have been land. The chief of these plants was a fern, Glossopteris. On its borders, at least, much of this continent was high and mountainous; so much so, that the peaks were snow-clad, and glaciers descended far into the forest-covered valleys—so low, in some cases, that we are driven to consider the climate there as being much colder than in other parts of the Earth. The glacial conditions, however, had best be reserved for another chapter, since they did not attain their maximum till the next age.

INDIA AND CHINA.

Peninsular India also had some very cold parts in this age, or early in the Permian. Glaciers transported considerable quantities of stones and silt down from the higher regions into the hollows of the old Archæan land surface; some of the boulders were too large for streams to have moved anything like the distance which they can be proved to have travelled from their sources. After a time the ice died away, and a series of lakes flooded the lower country; herein grew the characteristic marsh vegetation, thus indicating that the climate had altered materially. Of the coal seams which these lakes have left us, three are 8, 9 and 10 feet in thickness respectively, and there are a great many others of thickness varying down to 1 inch—all this indicates the lapse of a very considerable time, besides many constantly changing conditions in the geography. In fact, the same conditions continued hereabouts until well into the succeeding age, the Permian. We may get an approximate understanding of this singular combination of ice and semi-tropical vegetation by considering the state to-day of New Guinea—a land where, at the base of the mountains, the vegetation is so dense as to be almost impassable, while up above, the serene and snow-capped peaks defy even the power of an equatorial sun. The resemblance is heightened by the fact that the old Indian icy land bordered a sea which covered the site of the Himalaya; and although the island masses of Muth and Spiti, and some volcanoes in Kashmir, rose out of this sea, its waters stretched far and wide both to the east and the west; and in them Fusulina lived in countless multitudes. On the one side the sea buried Afghanistan, Baluchistan, and the countries bordering both sides of the Persian Gulf; on the other, the Northern Shan States. The ocean stretched so far north that it eclipsed the Northern Urals, where are now to be found the characteristic

Fusulina limestones (105). A long, narrow strait, running roughly from north to south through Burma, opened into another sea, part of which covered Sumatra and Indo-China, while another and greater part enveloped much of China proper and Japan. Here, also, great marshes fringed the shores of nearly every land, and valuable coalfields were thus, so to speak, put on order. The most important of the Chinese coalfields, however, are very much younger, and will be referred to again.

We cannot leave the East without just mentioning one of the most marked features of its geography, *i.e.* the great depression which extends at the base of the Himalaya, from the Indus to Assam. This is a line of weakness in the Earth's crust, which is believed to have come into existence during the Coal Age, and to have persisted ever since.

Australia also had Coal Forests.

The principal deposits of the Coal Age in Australia are found along the east and south-east coasts, stretching from Victoria well into Queensland. Much of the region was probably above water during the earlier part of the age; but the coal deposits only attained their maximum when the period ended elsewhere. Here, as in India, snow-clad mountains bordered the Gondwana continent; and the waste from the glaciers seems, in this district, to have been precipitated directly into the sea—just as it is to-day in the high southern and northern latitudes of Tierra del Fuego and Alaska.

South Australia, at this period, was a part of a continent which sloped north instead of south. It stretched far to the south over the present sea floor, and its rivers drained northwards. Here, also, ice was at one time very conspicuously in evidence.

New Zealand, which had undergone numerous but little-known vicissitudes during the preceding epochs, was at this time completely blotted out by the ocean.

COALFIELDS OF CONTINENTAL EUROPE.

In thus drifting, as it were, from one coal basin to another, we come back to Europe, for which we can spare only the briefest of references, although its coalfields are both numerous and important. Thick deposits of this age are found both in the Upper Loire and in the Pyrenees; and, towards the close of the epoch, the centre of France formed an island, whose shore, fringed by many lagoons and marshes, sheltered many a giant tree besides hosts of the commoner plants. In the basin of St. Etienne, near Lyons, a fossil forest, among other things, may be adduced as evidence of this.

IMMENSE GERMAN COALFIELDS.

During the earlier part of this epoch, the Ruhr District was for ages a lime-forming sea basin, which later became filled and converted into the familiar marshy lands. At Essen, no fewer than 145 times did the land and sea each gain the supremacy, with the result that 145 beds of coal were formed, having a total thickness of 364 feet (106). This is, of course, far greater than the corresponding series in Britain; and if we assume that the coal accumulated at the same rate in both areas, the Ruhr one would require $1\frac{3}{4}$ millions of years for the coal alone to gather.

The enormous value and importance of the German coalfields may be illustrated by another example. In Upper Silesia the coal seams of this age number 104, with a combined thickness of 505 feet! (107). How many eons of time this vegetable cemetery represents, we leave to the imagination of the reader. It is only when we remember that one can calculate that time (within limits), and that one can compare it with periods even more immense, that the majesty of the human intellect becomes really apparent. One very remarkable circumstance concerning this region is that its remains only correspond to the *lower part* of the Coal Measures of England. Farther east, as in the South Russian field, the coal beds correspond to the great limestones of the English area; and while in the latter the coal forests were growing, in Russia, on the other hand, the shelly homes of Fusulinas were being quietly and silently buried in ooze.

DEEP SEA ABOVE THE SITE OF THE ANDES.

Before quitting this part of our subject, we cannot refrain from drawing attention to another very striking instance of the great changes which the Earth's crust has undergone, and which is exhibited in the heart of the Peruvian and Bolivian Andes. There, at a height of over 13,000 feet, limestones have been found which were deposited in the Carboniferous sea, with the same kind of marine remains as have been found elsewhere (108). Calamites and tree ferns have been found near Pisco, on the Peruvian coast: a relic of early Carboniferous times (109). It has been regarded on strong grounds as probable that the elevation of the Eastern Cordillera of the Andes in the Illimani region originated in the early part of the Carboniferous, and it may have survived all the many vicissitudes which the neighbourhood has undergone since, continuing unbroken, except for minor submergences, till the present day (110). The great *mass* of the Andes, however, is immensely younger. North of the Andes, Gúatemala and Honduras lay beneath a Fusulina-crowded sea.

CARBONIFEROUS PLANTS IN THE SAHARA.

One last reference must suffice. The fossil tree Sigillaria, one of the most characteristic of Carboniferous plants, has been

Pl. 46. *L* 160.

Some Carboniferous Ferns (p. 166).

1, 5. Sphenopteris. 2. Rhacopteris. 3. Asterophyllites. 4. Neuropteris.

Pl. 47. *L* 161.

Sigillaria, a Carboniferous Tree (p. 167).

Trunks have been found up to 70 feet long.

found in the heart of the Sahara Desert; from which it is to be concluded that a part, at least, of that great waste continued at or near sea-level for long ages after its well-attested Devonian submergence.

Importance of the Age.

Although I have treated of this age at considerable length, yet it is with a brevity which does justice neither to the magnitude nor the importance of the subject; and the reader who desires to pursue his studies into the Earth's past story will find much in textbooks and special works on the Coal Age to interest him. I must again warn him that all the world's coal is *not* of this period: very important deposits of much later age existing in many countries, as I shall show hereafter; although our wanderings will take us through some strange places, and past many uncouth and fearsome creatures, before we again find ourselves in the pleasant, if somewhat stuffy and samely atmosphere of a coal age.

Animals of the Coal Age.

Although the fauna of the Coal Age, because of its very great development by comparison with previous epochs, has much general interest, it cannot compare in that regard with the plants; but we will glance at it in passing. Of the last of the Trilobites, Phillipsia, we have already spoken. It, and three allied forms, struggled through the period, degenerate in form and diminished in numbers; but as the last forests sank beneath the entombing waters, the great race of the trilobites was about to expire. Their nearest allies, the Horsehoe Crabs, were also sparingly represented; while the Eurypterids, having become wholly freshwater in habit, finally became extinct in the meres of the coal forests. Such crustaceans as were at all abundant included more modern forms; and Decapods (Ten-feet), of which Lobsters, Hermit Crabs and true Crabs are prominent members, came into existence at this stage. The next higher form in the armoured, articulated animals, the Scorpions, also got a firm foothold in the coal forests. Scorpions, as is well known, are remarkable for the number of eyes they possess: an early form, found in the Coal Measures of Bohemia (Cyclopthalmus), had twelve eyes, disposed in a circle. All the Scorpions of that age had the characteristic formidable nipping claws which are found in their modern representatives.

Many Insects.

Insects were numerous; for the damp and heat and vegetation seem to have especially favoured their development. Along the trunks, dead and alive, ran nimbly the oldest of Spiders; while Millipedes and Galley Worms, the leaf destroyers, also enjoyed an easy existence amidst such umbrageous surroundings. Their remains have occasionally been preserved in the hollow trunks of decayed forest giants, along with land snails and other fossils. One of the Galley Worms (Xylobus), at least, possessed the same power as its modern representative, of folding itself up into a ball; a device which did not prevent it from being preserved fossil. Another form (Euphoberia) was protected from attack from above, by a dorsal armour of spiny plates. An insect of somewhat terrifying aspect must have been a Carboniferous Dragon-fly, which possessed the enormous wing-spread of 28 inches (111). A specimen, that may have been 15 inches across the wings, was recently found in the Bristol coalfield. Fireflies and May-flies were also fairly common—much more so, for a certainty, than is indicated by the few remains that by chance have been preserved. There were also ancestors of Bugs, Plant Lice and Scale Insects; and a singular but doubtful form (Lithomantis) allied to the modern Praying Insect. Even the ancestral Cricket had come into being, complete with the peculiar arrangement of veins and wings which enables it to make its "call." Of the Cockroaches, according to the eminent American authority, Professor S. H. Scudder, there were no less than 16 different genera and 193 species, in addition to a very large number of yet undetermined forms; and of 78 species in two fairly close localities, one in Ohio and the other in West Virginia, not a single form was common to both (112).

Of the "beauty" insects, however—butterflies, moths and bees, one finds no trace. Nor ought we to expect them; for they accompany the flowers, and flowers were a thing unknown in the Carboniferous forests. Ants and true flies were also not yet created; and it is doubtful whether even beetles had learned to crawl from under the stones.

Protective Mimicry of Insects.

A singular circumstance, of great significance in one respect, is that even thus early, insects had commenced to mimic their surroundings, for protective purposes. "The first cockroach ever described was first described as a fern leaf; and in all or nearly all the localities where their remains have been found, they are associated with fern leaves in immense abundance" (113).

Gigantic Ancestral Newts.

The denizens of the green Carboniferous wildernesses, apart from the above insects and a few snails, appear to have belonged wholly to one or two backboned forms, very low down in the vertebrate scale—to wit, tailed amphibians, generally resembling the modern newts and salamanders, but of very different proportions. They had a long body with relatively weak limbs and a long tail, and were protected by an armour of thick, wedge-shaped plates, arranged in rows like the tiles on a housetop. They are known as Labyrinthodonts, from the extraordinarily complex and labyrinthine folds in the microscopic structure of the teeth (Plate 48, 7). There were numerous genera, more or less distinctive, and mostly of small size; but some, *e.g.* Anthracosaurus and Archegosaurus, were relatively gigantic, with heads 15 inches long, and the overall length of the body ranging up to 3½ feet (Plate 48). In the land conditions which succeeded the Coal Age, these earliest vertebrates attained much greater dimensions, as will be shown later. Those of the Coal Age are interesting for the links they form in the scale of organised life; for the least developed of them is of larval aspect, and one form (Ophiderpeton) may have been devoid of limbs. They must have come, in the first instance, from the water. For, as a class, the amphibians commence life as water-breathing larvæ, provided with gills; but on attaining the adult state, acquire lungs. In some cases both gills and lungs are retained throughout life, whilst in others the gills disappear. The limbs, however, never develop into fins. These facts, coupled with the fish-like structure of certain genera, tempt one to imagine them as having slowly evolved, in the midst of the Carboniferous marshes, from true fishes; first wriggling helplessly among the slime, and afterwards gradually acquiring lungs for breathing air and limbs for locomotive purposes, and lastly, their strong and peculiar teeth for masticating the vegetation on which they may be presumed to have principally lived. We shall have more to say on this subject in a moment. Not the least interesting traces which the Labyrinthodonts have left of their existence are the many footprints in the mud; but whole skeletons have also occasionally been preserved.

Coal Age Fishes.

Fish were very abundant during the Coal Age; and it is curious to note that the species of sharks and rays now outnumbered the enamelled fish by nearly two to one (114). There was a great abundance of mud-frequenting forms; and we may well believe that these sheltered themselves in the weed-choked and narrow creeks that fringed most of the low shores. There were numerous plaice-like fish (Platysomus); and an ally of the terrible Holoptychius (Rhizodus) made its appearance, and was equally well provided with weapons for exercising its voracity. The Rays and Skates, the oldest remains of which are found at this time, must be distinguished from the true flat fishes, by remembering that their flat appearance is largely due to their very large pectoral fins; and the whole body is flattened, whereas in a true flat fish the body is shaped like that of an ordinary fish in its earlier stages, and is only later flattened from side to side, the head being twisted so as to bring both eyes on one side of the body. There were no true flat fish, so far as known, in any age so old as the Carboniferous.

The Modern Barramunda.

We may here appropriately refer to a singular modern type of mud fishes, allied to certain Coal Age forms; its name is Ceratodus, although it is locally known in its native rivers of Queensland as the Barramunda. This appears to be a very strong link between the fishes and the amphibians. It is also intermediate in structure between a Devonian form (Dipterus) and a Triassic form (Ceratodus), and it has an analogue in the Coal Age named Ctenodus.

The Barramunda attains a length up to 6 feet. Although eel-shaped, on the whole, it is thicker and shorter than the common eel, and is, moreover, covered with very large scales.

"The head is flattened and broad, the eye lateral and rather small, the mouth in front of the broad snout, and moderately wide." Its teeth are "entirely similar to the fossil teeth of Ceratodus. The incisor teeth are used in taking up or even tearing off leaves, which are then partially crushed between the undulated surfaces of the molars" (115). The skeleton is in the form of cartilage. The Coal Age form, Ctenodus, had enamelled cranial plates, and its scales were oblong-shaped, thin and delicate.

Carboniferous Fungi.

Coming to the plant world, we find that Fungi were preserved within the wooden stems of higher types; one of them is remarkably like the fungus which causes potato disease (Peronosporites). Other types grew parasitically upon ferns. Ordinary plants, of course, derive their nutriment directly from the air and the soil; but Fungi, like animals, cannot do this. They are reduced to the necessity of taking up their abode on other forms, and abstracting their nutriment from them—a mode of slow suicide, in fact, for when they have killed their host they themselves must perish.

Ferns.

Ferns were most prolific, both the common types and tree ferns more or less like the living tree ferns of New Zealand. The bracken-like Alethopteris now attained its maximum. The leaves of one fern (Neuropteris) are markedly similar to the wings of certain cockroaches, as already remarked (Plate 46, *4*).

Tree Ferns.

Of the larger plants, we have already referred to Calamites, which was as abundant in the Coal Age as in the Devonian.

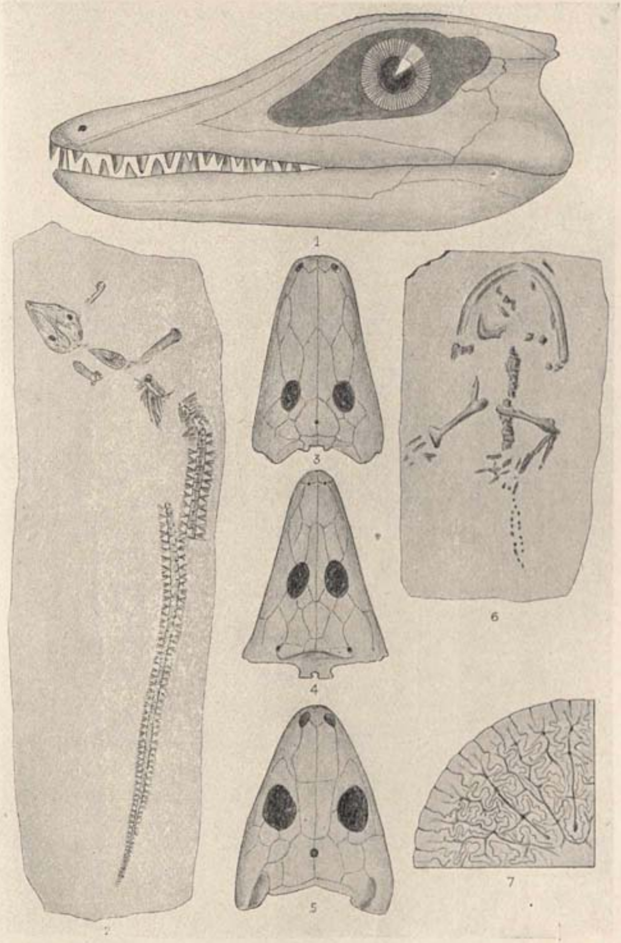
The tree fern, Lepidodendron, attained a length up to at least 50 feet, and gave off branches in a regular, bifurcating manner. The bark is marked with numerous scars, indicating the points where leaves were formerly attached; pieces of this bark are frequently to be found in any one's cellar. "The branches were covered with slender pointed leaves, closely crowded together, and the fructification was carried at the ends of the branches, in the form of cones or spikes" (116). In some of the English coals, the mass of the coal is actually made up of the spores of club mosses (117): another indication of the slowness of the coal formation, for the spores are only visible to the eye as minute brown specks.

SIGILLARIA.

Another tree, Sigillaria (Plate 47), was even larger than the Lepidodendron; one found at Newcastle-on-Tyne had a length of 72 feet. The bark of this tree was strongly ribbed or fluted; and each of the ribs contained very numerous seal-like marks (hence the name: sigilla = a little seal) which were the scars left after the long narrow leaves had fallen off. Its massive roots, known as Stigmaria, are very common in the underclay which forms the floor of each bed of coal, and which represents the ancient soil upon which the tree grew. It is a matter of dispute whether this noble tree was allied more closely to the Club Mosses or to the Cycads (Palms). Coniferous trees, typified by ancestors of the Araucarian pine, doubtless clothed all the uplands; and their trunks were sometimes drifted down to the coal forest marshes and mired there.

LACK OF VARIETY IN CARBONIFEROUS FORESTS.

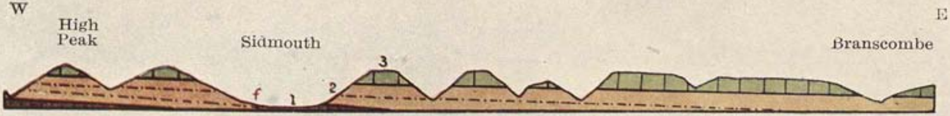
These, together with various reeds and sedges (and, of course, the ubiquitous pond- and sea-weeds), appear to have made up the whole of the plant life of the Coal Age ; although there were, almost for a certainty, various upland forms whose identity may never be known to us. The absence of honey-loving insects indicates that although this terrestrial paradise was green, it was nothing more than green. The exquisite flowers which adorn our gardens were unknown ; so were the long stetching meadows, dappled with the gold of the buttercup and the white of the daisy. "With all the luxuriance of the foliage, and the denseness and stature of the trees which overspread the great lagoons of the Carboniferous period, the general effect must have been sad and sombre in the extreme. But it persisted through long ages in unspeakable loneliness and silence, echoing neither voice nor sound, except when some giant of the forest snapped in twain and fell heavily into the arms of its companions" (118).



Pl. 48. *M* 168.

Labyrinthodonts (pp. 163-4).

1. Loxomma. 2. Ptyonius. 3. Capitosaurus. 4. Mastodonsaurus.
5. Rhinosaurus. 6. Pelion. 7. Labyrinthine Tooth.

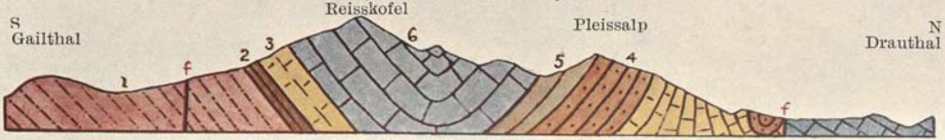


A : English Coast near Sidmouth.

1. Triassic Sandstone. 2. Triassic Marl. 3. Chalk and Greensand.

B : Near Mt. Wrangell, Alaska (after Moffit).

1. Pleistocene Igneous Rocks. 2. Carboniferous. 3. Triassic Greenstone. 4, 5. Limestone aud Shale 6. Jurassic 7. Recent Gravels. 8. Dyke.



C : The Alps. Reisskofel (7870 ft.) and Pleissalp (5635 ft.). (After Geyer).

1. Permian Sandstone. 2-6. Trias. 2. Werfen. 3. Muschelkalk. 4. Wengen. 5. Wettensteinkalk. 6. Dolomite. f.f. Faults.

Pl. 49. *M* 169.

Sections through Triassic Rocks.

CHAPTER VII.

The Age of Deserts (*Permian and Triassic*).

DIFFICULTIES OF INTERPRETATION.

WE now arrive at a chapter of the Stone Book which is as full of interest as it is of obscurity. It deals with land deposits on a large scale; and these, because of their ambiguous appearance when seen in the field, are far more puzzling to the geologist, and far more susceptible of different meanings, than the comparatively simple deposits which are laid down in an estuary or on an ocean floor. Hence, in this chapter, my interpretation of the story must be taken to represent, not the united opinion of students of Earth history, but only that which appears to me to be the most probable and reasonable.

THE TWO AGES, PERMIAN AND TRIASSIC.

For the purpose of conserving space, two great divisions of the Stone Book are here merged into one. The older is known as the Permian, because its rocks are very well exposed in the province of Perm, in Eastern Russia. It followed immediately upon the Coal Age, from which, in many parts of the world, its lower portions have been separated by arbitrary divisions only, so gradual was the change from the one age to the other. In other parts, however, and notably in England, vast changes took place after the Coal Forests had died away, before ever a single fragment of Permian rock was laid down. The younger division is variously known as the Trias (from its well-marked threefold character in Germany) and the New Red Sandstone, in contradistinction to the Old Red Sandstone of Devonian times, which it superficially resembles. It covers a much more extensive area than the Permian, and has consequently, been more closely studied. Between the two, a well-marked line has been drawn separating the earlier forms of life from those of the Middle Ages of the Earth ; for the Permian is allied, both by its plant and its animal remains, to the Coal Age ; whereas the Trias inaugurates the Age of Reptiles and Cycads. Nevertheless, the geographical peculiarities of both periods are so similar, that I feel justified in here presenting them as one.

BRITAIN PART OF A CONTINENT.

Towards the close of the Coal Age, many of the continental masses whose rivers and shorelines furnished the coal-forming marshes were raised high above the sea, and their borders gradually extended—so much so, in fact, that most of the areas which had been sea in the Carboniferous Limestone epoch, now became a part of the land. Such an uplift affected practically the whole of England, which became part of a continent that stretched certainly far to the west of Ireland on the one side, and to the confines of Asia Minor on the other. The line of moor-clad hills which, although greatly worn down by the storms of countless centuries, still forms the backbone of our country—the Pennine Chain—had its origin in this uplift; and as the limestone of which the Pennines are mainly composed was at that time covered by an enormous thickness of coal beds and Millstone Grit, all of which was removed in some parts before the first Permian rocks were deposited upon its scarred and fretted surface, we may safely conclude that it formed a mountain chain 8,000 to 10,000 feet high at the least, extending from the Cheviots to Derby, and having its real height made more impressive by the low plant-choked morasses which surrounded it. In the neighbourhood of Derby, the main chain split up into a number of subsidiary ridges, which radiated in long finger-like projections to the south-west, south and south-east. One of the principal hilly areas stretched across Shropshire into South Wales, where it assumed an east-west direction.

Another great line of disturbance and uplift ran down the middle of the English Channel (119), elevating the bed of that shallow sea into an imposing east-west trending mountain range. This disturbance, having its origin, apparently, in violent pressures from the south northwards, had so great an effect on the neighbouring lands that the rocks of Devon and Cornwall were completely buckled up, and transformed into the confused mass of slaty rocks which are so conspicuous a feature of those counties to-day (Plate 35, B). In addition to being violent, this disturbance was of far-spreading magnitude. It has been traced on its eastern side through a large part of Europe, and on its western side across the south of Ireland. The highlands it created formed, in all probability, the core of a much larger Europe than at present exists. Going east, however, the land gradually declined in altitude, until in the steppes of Russia it sank beneath a shallow sea.

VAST MARSHES.

These early Permian mountains were bordered by vast stretches of low, marshy, vegetation-crowded ground. Such an one is believed to have covered the centre of Ireland, the Irish Sea and the fringe of the western English counties; and out of this marsh arose the forest-covered slopes of the Pennines on the one side, of Donegal on the other, of Antrim on the north, and of the newly-created McGillicuddy's Reeks on the south. Other low and marshy lands abutted on the mountain axis in Bohemia and Silesia, where the conditions of the

Coal Age lingered undisturbed for many centuries. Far to the north, also, the same marsh-loving plants, and the same warm and humid air, were to be found in a sunny, and no doubt, picturesque Spitzbergen.

Creation of Appalachian Mountains.

As was only to be expected, these great changes in the aspect of Europe were not confined to that part of the globe, but had their repercussions in many other quarters. In the eastern United States, similar movements were present on the most gigantic scale; for it was at this time that the many-ridged Appalachian Mountains, the highest land on that side of the continent, had their birth. As we have seen, ever since Cambrian times their site had been a long, narrow and protected sea, wherein over 20,000 feet of sediments had accumulated. On the eastern side, this sea was bordered by the abrupt margin of a high land, the eastern shore of which extended far to the east of the present Atlantic seaboard. On the west, however, the Appalachian Sea had, intermittently, the lowlying lands of Wisconsin, Illinois, Iowa, Indiana and Ohio; all of which, though in themselves not particularly capable of resisting strong pressure, lay on an extraordinarily firm and solid foundation of pre-Cambrian rocks. As the Coal Age expired, this part of the Earth appeared to tire of its featureless history, and set about changing in no uncertain fashion. Under the Appalachian Sea, lines of weakness developed; and at the same time, well out in the Atlantic to the south-east and east, forces were piling up an angry energy which at length, bursting all bounds, directed an enormous pressure upon the lands to the north-west and west. The pre-Cambrian base of the central States held firm, but the bed of the Appalachian Sea did not. The pressure, greatest on the lower and more deeply-buried layers of rock, moved many millions of tons forward upon the expiring sea, in a series of great waves, as of a frozen ocean. Over the latter arose a mountain area 450 miles long and 100 miles wide. Owing to the unequal hardness of the rocks, and the long-continued persistence of the pressure, they were not only folded like layers of wax, but were badly fractured at weak spots such as the junction of hard and soft beds, the former being thrust bodily over the latter for considerable distances. The combined result of all these movements was the reduction of what had been a surface 100 miles wide into one of 65 miles (120), having a very considerable elevation above the sea, and undoubtedly possessing a most confused topography. The most extraordinary feature of these movements was their regularity over great distances. Ordinarily, earth movements of a rock-shattering nature affect comparatively small areas; but the Appalachian folds were persistent over hundreds of miles—for example, one fold alone is no less than 375 miles in length (121). It was as if some prehistoric Atlas had set his gigantic shoulders, spanning 375 miles across, against that part of the Earth and pushed it along in one solid wave. Of the great mountains which were created by these disturbances, nothing now remains except their roots.

Farther to the west, in the Allegheny Plateau, the effects of these great movements grew less and less, until they finally died out altogether. But it seemed that the subterranean demons had conspired all over the Earth to change its face; for practically all the centre of North America emerged in these days above the sea, some of it for the last time. The eastern half of the Cordillera, too, comprising the Rocky Mountains, and the Selkirks and associated ranges, probably increased considerably in height and grandeur. A great dome-shaped mass of land in the Missouri-Kansas region, the ancestor of the present Ozark uplands, had been steadily climbing higher out of the water since Carboniferous times, and the finishing touches were now added to its elevation. Yet, with the true inconstancy of nature, a little area of sea long persisted in south-west Wyoming, and another in the Inyo region of California; but both were later cut off and evaporated away.

The Age in Canada and Alaska.

The central parts of Alaska formed a sea-bed at this time; but it was ringed about with active volcanoes. A long line of similar smoking cones (some of which must have presented a majestic appearance, with their dark sides and glowing summits rising thousands of feet above the ocean) stretched through the whole length of a sea that covered western British Columbia and Vancouver Island. There was sea, also, in the extreme north of Canada, mingled with intermittent volcanic activity; but to the east, Labrador, presumably, presented an aspect which it had already worn for ages, and which it was destined to exhibit right down to historic times—a gnarled and rocky mass, impervious to all the changes that went on around. As a minor result of the Appalachian mountain-building, the lower St. Lawrence region was now raised above the sea; and the estuary, thus properly defined at last, remained in that condition until relatively recent times.

Slow Progression towards Modern Geography.

Thus, as we trace our way slowly from page to page of the Stone Book, first one familiar form and then another comes into being; and the Earth, bit by bit, takes on some semblance of its present aspect. So far, these fragments have been few and scattered; but they will grow in number rapidly and ever more rapidly as we proceed, until at last we shall no longer be able to keep pace with them, and the Earth as it is will lie before us. There is a strong resemblance in all this to the work of the seeker after knowledge. The few scattered facts with which years of painful groping have presented him may seem, as he sourly contemplates them, to be of little worth, compared with what he still has to learn; yet as he goes on, more and more fragments of truth are brought home to him, and the materials secured for a mosaic which other hands may later build into a beautiful and inspiring temple.

GONDWANALAND.

Glancing, for a space, at the other half of the world, we find there also a great accession of land. The continent, known as Gondwanaland, which had been so prominent in the Coal Age, now extended, in all probability, in one unbroken mass from South Central Africa to the Indian Peninsula, and thence, by way of the East Indies, into Australia. Its north-west border was in the region of the Persian Gulf, where there existed a deep sea, crowded with surface-loving animalcules, and with corals and all the other denizens of tropical marine waters. The northern border of Gondwanaland, between the Pamirs and the Himalaya, appears to have been exceedingly irregular—sometimes sea and sometimes land; and hereabouts grew a considerable amount of coal-forming vegetation. From the site of the Himalaya, its border extended across the Shan States and the East Indies into Australia, being terminated on the east by the low and marshy flats of Queensland and New South Wales. Part of that Himalayan sea-bed is now to be found at the greatest altitude to which mountaineers have yet climbed, on the sides of Mount Everest (122).

A LOCAL "ICE AGE."

There were some strange anomalies about this old continent of Gondwanaland; for despite its tropical situation and its wealth of warm-climate plants, it boasted not only high mountains which rose far above the snowline, but also had a considerable development of local glaciers, which must in some instances have crept nearly if not quite down to the level of the sea; thus paralleling the peculiar aspect of parts of Patagonia at the present day. It is possible that at that time the climate of the equatorial regions was considerably colder than at present; for although each system of the old glaciers seems to have been restricted in its range, they were found over so great an area that the land must have been exceedingly high or else the climate unnaturally cool. Thus, rock surfaces which were almost certainly polished and grooved by ice, and great boulders that only ice could transport, together with other indications of a glacial climate, have been found in Cape Colony, in the Transvaal, in Central India, in Kashmir and possibly in the Urals, in New South Wales, Victoria and Western Australia (123). They have even been recognised in Brazil; which was, in all likelihood, then a westerly extension of the high African land mass. How much farther to the west this great latitudinal land mass ran we do not know; but it is almost certain that parts of the Eastern Cordillera of the Andes were then above the sea (124). Nor do we know how far to the south the continent extended. It presumably reached far beyond the parallel of Cape Town; for the north of Cape Colony, with a large part of Bechuanaland and the Protectorate, the Transvaal, Southern Rhodesia and Mozambique, formed a complicated mountain area (125), with a strongly continental climate. Gondwanaland ferns occur in the Falkland Islands.

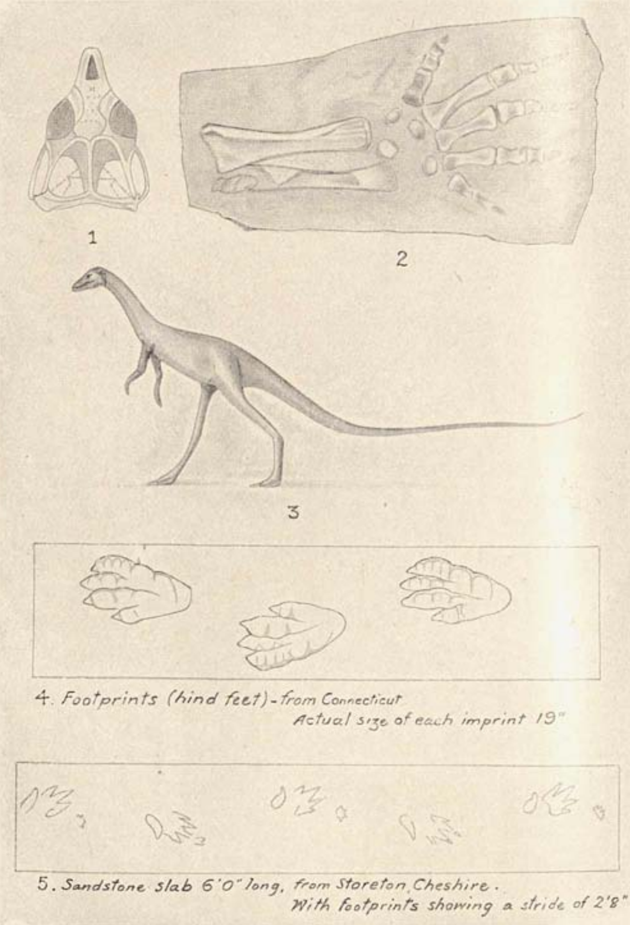
New Zealand did not belong to Gondwanaland. It was part of a large island lying some distance to the east of the continent, and may have extended as far north as New Guinea. It appears to have been a high land, with a cold temperate climate, and was very unlike the New Zealand of to-day (126).

Pl. 50. *M* 176.

The Canyon, Zion National Park, Utah (See Page 180).

The older rocks of this canyon are of Triassic Age.

(Courtesy Union Pacific System).



Pl. 51. *M* 177.

Triassic Reptiles.

1, 2. Rhynchosaurus. 3. Podokesaurus, 3ft. 9in. long (after Lull).
4, 5. Footprints.

PERMIAN DEPOSITS IN BRITAIN.

Ages passed, during which all these lands were slowly worn away, before any appreciable amount of Permian rock was laid down in areas now exposed to view. So great was this interval in certain districts, such as the north of England, that the whole of the vast thickness of Coal Measures and Millstone Grit was removed, and we find the oldest Permian rocks resting upon the worn surface of the Carboniferous Limestone. Eventually, however, the lower-lying lands were sufficiently depressed to permit the ingress of the sea. One such incursion extended westwards from the Pennines across the site of the Irish Sea to the Antrim coast. Another, lying to the east of those mountains, covered parts of the north-eastern counties and the bed of the North Sea. Southwards, these waters communicated with a great depression in the Midlands, extending from Leicestershire to Wales, and having ramifications that stretched as far south as Exmouth on the Devon coast (Plate 46). This invasion, however, was of slight duration; but the subsequent uplift was equally abrupt, and large areas of the sea were cut off, being converted into salt lakes. Receiving the drainage from the surrounding districts, and possessing no outlet, they grew steadily more and more saline. While their storm waves were breaking up the rocks on the shores into coarse gravel, the chemical changes induced by the increase in salinity were resulting in deposits of various salts farther out. The face of the country must have worn a remarkable aspect during these changes. It seems likely that most of the upland vegetation which had characterised the beginnings of the continent—mostly a monotonous array of Araucarian Pines—long continued to exist; and we may conceive that much of England comprised such wooded islets, rising out of the shallow, brooding waters of the lakes. Where the coast was sheltered, stretches of reeds doubtless stood far out from the shore; and in the mud flats whereon they lived, congregated a sparse but singular assemblage of newt-like creatures, 2 to 4 feet in length. Life as a whole, however, seems to have been conspicuous by its absence. The wealth of spiders, dragon-flies and cockroaches of the Coal Age forests had passed away; the fish were few and scattered, except in the distant ocean; the only things that developed much were the reptiles (Plate 51); and in our islands even they throve ill. This paucity of life may have been directly caused by changes in climate; for the latter appears to have grown steadily drier, and perhaps colder. In the higher regions, the precipitation took the form of snow, which the sun had not sufficient strength to melt. By degrees, the snow changed to ice; and small glaciers, whose snouts terminated in the lakes, sent off bergs and berglets, loaded with stones, on erratic voyages at the caprice of the winds and currents. Such transported pebbles have been found over a wide area in the Midlands, and also on the north-eastern Irish shore. But though Britain was thus cold, it was far from devoid of heat; for the volcanic fires of southern Scotland, which had been a marked feature of the Coal Age, again burst into prominence; and Ayrshire, in particular, presented a singular example of extreme heat adjacent to equally extreme cold.

Exceedingly Ancient Valleys.

We may here note an interesting example of the persistence of certain natural features throughout long ages. Some of the valleys of that volcano-studded area, notably Nithsdale and Annandale, are still existing to-day; the former, in fact, goes back much farther, *i.e.* to the early part of the Coal Age: it was buried beneath the Coal Measures; partly re-excavated during Permian times; buried anew in the volcanic troubles; and again re-excavated since (127).

The Magnesian Limestone.

The dismal picture changes, but not much for the better. The open sea, advancing from the north-east, invaded Northumberland, Durham and all the country as far south as Nottingham; depositing thereon a mass of impure yellowish magnesian limestone or dolomite. After a considerable interval, a slight elevation of the land seems to have treated this sea in the same manner as its immediate predecessors, and to have converted it into a closed basin which gradually evaporated away. The life in and around this lake, though considerably more varied than that of the early Permian, still exhibited a paucity of types.

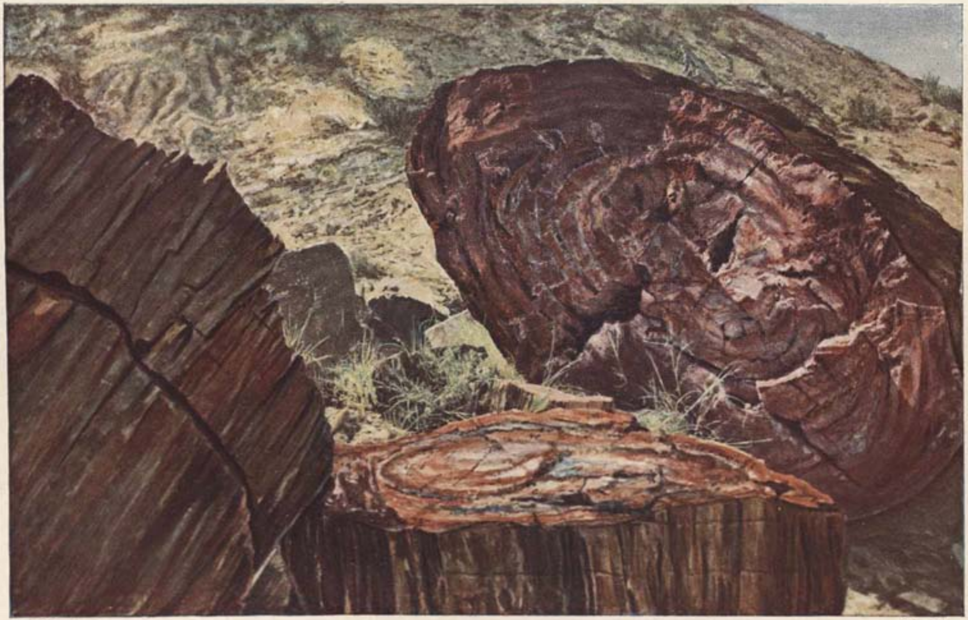
The Permian Abroad.

This meagre record is all that Permian time has left us in England. Its deposits, however, were much more imposing in other parts of the world. For example, in the Province of Perm, the sediments laid down in a cut-off arm of the sea covered an area twice the size of France: masses of white limestone in the main, with a considerable admixture of gypsum and salt that were thrown down as the salinity of the evaporating waters increased. Another large isolated sea basin, which afterwards dried up, covered Thuringia, and its *remanié* is well shown at Mansfeld. Here, again, gypsum and rock salt bear eloquent testimony to the gradual evaporation of the confined lakes and meres; and it is known from other evidence that the water in them sometimes attained the temperature of warm springs. These Permian rocks of Germany bear the fantastic name of Roth-todt-liegendes (red-dead-lying); it was given them by the miners, both because of their predominant colour and of the fact that the copper deposits of the region die out as soon as the red rocks are reached. The Permian landscape there must have been even more desolate at times than that of England; for the horrors of vulcanism were added on a considerable scale, and the ejecta of the volcanoes is found mixed with the red grits and sandstones that successively formed the lake bottoms. But at infrequent intervals the dry scorching winds and smoking cones seem to have lost their force, and pleasant groves and thickets to have sprung up along the stream courses; for no fewer than sixty species of fossil plants have been found there. Two-thirds of these were peculiar to that limited area—a sure indication of the abnormal conditions under which they grew; and of the remaining twenty species, which include silicified trunks and hefty tree ferns, a good number are closely allied to the plants of the Coal Age.

In North America, also, the great continental uplift was the means whereby vast areas of the sea were cut off and converted into saline lakes. One such lake stretched across parts of New Mexico, Texas, Oklahoma and Kansas, covering an area 650 miles from north to south, and 150 to 250 miles from east to west. Herein a very great mass of rock was laid down, including the largest known bed of salt in the world. This latter has the enormous thickness of 700 feet; and in many places a thickness of over 300 feet has been shown to exist, although the geology is as yet imperfectly known (128). When at last the waters of this large area had evaporated away, they left a surface of low relief that endured, presumably in a more or less desert condition, until the next or Jurassic Age. (*See also* Plates 50, 52, 53.)

Gradual Transition to the Trias.

Regarding the Earth as a whole, the arid and semi-arid conditions of later Permian times passed insensibly into those of the Trias; but locally there were great differences, caused, in some cases, by incursions of the sea and in others by the continued elevation of the land. Thus, near Spiti, under the shadow



Pl. 52. *M* 180.

Petrified Triassic Trees (see also Plate 53, and pp. 180, 188).

Pl 53. *N* 181.

Petrified Triassic Trees from Arizona (see also **Plate 52** and **pp. 180, 188**).

Some of these trunks were 200 feet long.

of the Himalaya, the deepening of the sea which hereabouts washed the shores of Gondwanaland, indicates a retrogression of the shoreline to the south; an abundance of coral reefs was formed here, and shallow seas endured until Jurassic times (129). A little farther east, however, in the northern Shan States, the Permian sea made way for a low but extensive land, with ramifications extending far to the north and south. Central China and Yunnan formed one of these contiguous lands; and here the conditions were suitable for the formation of beds of coal (130).

Gondwanaland once more.

The north-western border of Gondwanaland at first presented a marked contrast to the sedge-choked streams and the thickets and morasses of the north-eastern side; for here the new age was ushered in, in Baluchistan, Darwaz and Afghanistan, by a long spell of violent volcanic activity. After this had spent itself, however, the all-conquering plants took possession there also; and vast marshes, resembling those of the Coal Age, came into being, with intervals of greater or less submergence; whilst in the north and west of Afghanistan, the last volcanoes continued intermittently to spit out their venom as they expired (131). This land, which was half water, separated the Himalayan sea from another sea which covered south-eastern Europe. After several vicissitudes the area emerged permanently; and thus another piece was added to the mosaic of the modern globe.

Desert Conditions in England.

In England, conditions were slow to change. After the Permian lakes had died away, the country appears to have grown higher, and possibly wetter; and after an interval the duration of which cannot be measured, rivers, probably draining to the south and south-east from the mountains of Scotland and the extreme north of Ireland, and to the north-east from the high lands of Devon and Cornwall, built up large flood plains in the centre of the country (132). This was apparently an arid region, almost shunned by living creatures—at least, scarcely any have left a trace of their existence—and it may be that the rivers had no outlet, but lost themselves in the sand. The rainfall was most probably in the form of sudden cloudbursts—possibly, as in the deserts of to-day, a year's rain fell in a few hours—and it and the wind between them shaped the early Triassic rocks. They were effective workers, leaving a very rough and curious topography, with the older and harder rocks of South Wales and the Midlands standing like islands out of a sea of sands, their worn, scarred cliffs as rough and jagged as though the waves had only yesterday been beating upon them. This old topography is particularly well shown in Charnwood Forest and near Cardiff.

This part of the Trias is known as the Bunter. It closed, apparently, with a depression of much of the country to slightly below sea-level; and the next part, the Keuper, came in with a re-elevation, and the formation of another series of saline lakes. Stretching from Sidmouth (Plate 49, A) and West Somerset via the Severn and the eastern part of Hereford into North Wales; and thence far to the east, over Cheshire, Lancashire, Staffordshire, Derby, Leicester and the rest of the midland counties, they had a branch over the site of London, and may even have extended far to the east and south of the capital. They are of very great economic importance in our national life, these old red rocks; for the greater part of the Midland water supply is drawn from their pores. The lake beds are well represented as far north as the Tees on the east and Cumberland on the west; and they once covered the Irish Sea to the borders of Belfast Lough.

IMPRINTS OF REPTILES.

The increased humidity seems to have favoured life, which, though still poorly preserved, becomes abundant by comparison with the Bunter. Many salamander-like animals left their footprints, and occasionally also their bones, in the mud on the lake shores and river bottoms; and with them a few plants and fish remains have come down to us (Plate 51).

SALT DEPOSITS.

The great rock salt deposits of Cheshire and Worcestershire are of this age. They form lenticular bands from a few feet to 120 feet thick, and are usually reddish in colour, on account of their impurities. They are the products of the evaporation of the old Keuper lakes.

Similar conditions certainly prevailed at this time in much of Scotland. So much of the rock has, however, been removed since, that their identification is a matter of some difficulty; but they are well shown at Lossiemouth and Elgin, where they contain the bones and scales of a crocodile and of other reptiles. Similar rocks exist in Skye.

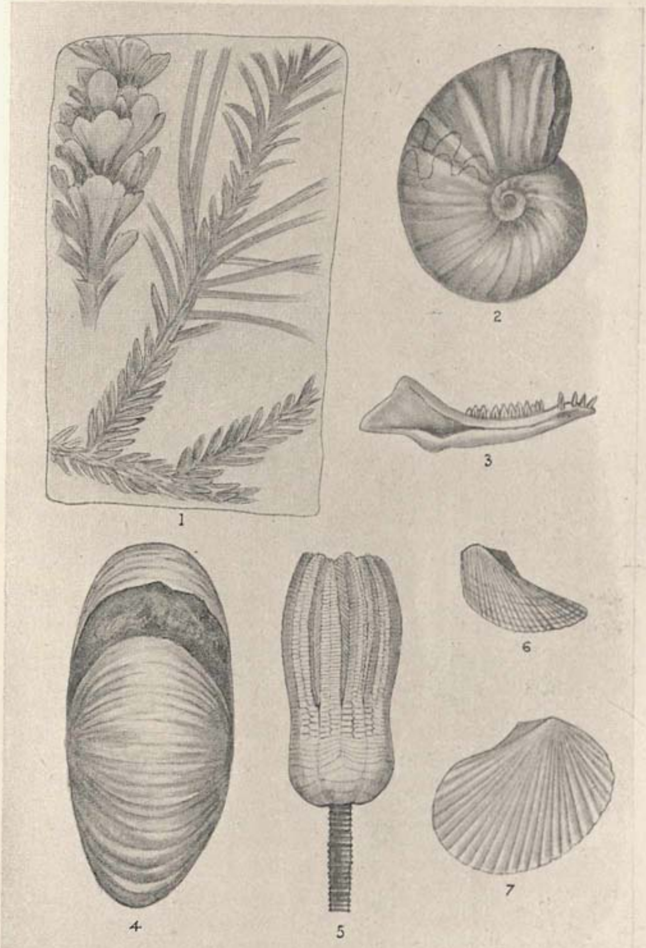
THE RHÆTIC.

When the lakes were nearly filled with sediment, the roughnesses that marked the inception of the Keuper had been to a great extent removed, and the land had, in general, the aspect of a low plain. A new submergence permitted the ingress of the sea once more, and so brought the age to a close. From its marked development in the Rhætic Alps, the rock deposited during this submergence, and whilst the sea was still doubtful of its conquest, is known as the Rhætic Age (Plate 49, C). It is interesting to find among its rocks, which are rarely more than

50 to 60 feet thick, a curious assemblage of marine and land animals, including sea lizards and small rat-like mammals —the latter being the first of that long succession of highly organised vertebrates which has terminated in man.

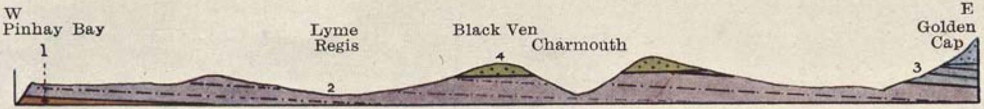
SALINE LAKES IN EUROPE.

So much for our own country. The story of the Trias on the continent was different. In brief, it contains two epochs of land, strongly marked by the presence of saline lakes; and between the two, an epoch of marine submergence. This is true only for that part of Europe lying north of the Alps; over the site of the Alps marine conditions prevailed on the whole, and farther south still they were uninterrupted. The low-lying lands of North Central Europe seem to have favoured repeated incursions of the sea at this time. For instance, in Alsace and Lorraine, there are no fewer than thirteen successive lenticles of salt, having a total thickness of 191 feet (133). These may be interpreted as representing thirteen successive periods during which the confined waters of a saline lake, or the partially confined waters of a lagoon, were replenished from the ocean and evaporated. Time equivalents of these lake beds, in the Tarentais, attain the excessive thickness of 13,000 feet; on the whole they were not so salt and not so heavily evaporated, most of the salts thrown down being gypsum. At Stassfurt, again, there are 3,000 feet of more or less pure gypsum and salt. We may here mention that both gypsum and rock salt are evaporated from sea water, the former when 80 per cent. of the water has evaporated, and the latter not until 90 per cent. has evaporated. Now, the amount of gypsum in 1 cubic foot of normal sea water is $\frac{3}{50}$ lb., from which it is plain that the amount of sea water necessary to yield 1 cubic foot of gypsum is 2,332 cubic feet. This will give some idea of the activity which went on in these old natural boilers.



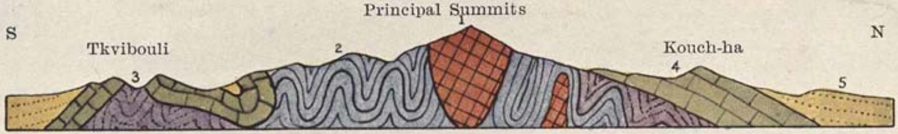
Pl. 54. *N* 184.

Triassic Life Types. 1. Voltzia. 2. Ceratites. 3. Jaw of a mammal, Dromatherium. 4. Halorites. 5. Encrinus. 6. Avicula. 7. Monotis.



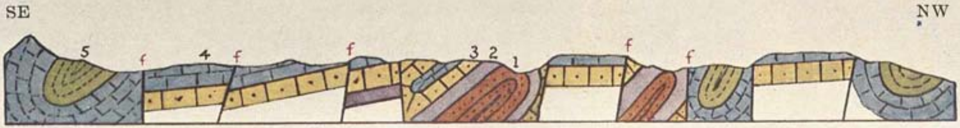
A: Lyme Regis (after Woodward).

1. Rhaetic. 2. Lower Lias. 3. Middle Lias. 4. Cretaceous.



B: The Caucasus (generalised, after Fournier).

1. Gneiss & Schist. 2. Palaeozoic. 3. Jurassic. 4. Cretaceous. 5. Tertiary.



C: The Jura, Franche-Comte (after Fournier).

1. Trias. 2. Lias. 3, 4. Middle & Upper Jurassic. 5. Cretaceous. f.f. Faults.

Pl. 55. *N* 185.

Sections through Jurassic Rocks.

It must not be assumed, however, that all the salt beds were obtained in this way; on the contrary, they are sometimes the product of very complex chemical changes, due to the lower layers of the water becoming steadily salter, while the surface layers remain more or less normal. As an indication of the occasional or general warmth of the climate, it has been shown that some of the Stassfurt salts could not have formed until the water had a temperature of 160° Fahr. (134). Bodies of hot water of such magnitude as these must have reacted in a marked manner on the temperature of the air. There was, notwithstanding, sufficient humidity for a moderate number of plants to exist; principally cycads (which resemble young palms), ferns and coniferous trees, including an early form of cypress. The climate was cooled, moreover, by the presence of deep water in the Mediterranean, where many generations of animals, representing transitions between the old forms and the new ones, lived and died.

The Newark Lagoon.

One of the most interesting lagoons in the world in this age has left its remains in eastern North America. It has been remarked already that the maritime provinces were formerly very high land, and that the ocean border was much farther to the east. In Triassic times, one of the after-effects of the Appalachian mountain-building was the relative depression of this old land, and the formation of a great system of lagoons, extending all the way from North Carolina to Nova Scotia; well tenanted by fish of various kinds, and having on their shores a variety of beautiful and peculiar plants. Among the latter were the Ginkgo, or maidenhair tree, cycads, horsetails and the very handsome broad-leaved fern, Macrotæniopteris. The vegetation sheltered and provided sustenance for a large number of weird crocodiles and lizards, of which more anon. These lagoons persisted throughout the age, despite the efforts on two or three occasions of volcanic eruptions to destroy them. Far above the green shores towered the Appalachian Mountains, which were still, of course, relatively young; and it is believed, from many circumstances, that they were snow-clad. A strange contrast, all of it, with the innumerable railway lines, cultivated fields and busy human activities of the district to-day!

Permian Coalfields in South Africa.

One permanent mark which these ages have left on the land is to be found in the heart of Africa, in Katangaland and Rhodesia. Here, in Permian times, freshwater marshes existed, the vegetable remains of which have now become valuable coalfields—the Wankie Coals. On top of these, and presumably of Triassic Age, a large number of lava floods were poured out from fissures, to a total thickness of over 1,000 feet (135). These sheets of volcanic rock, known as the Batoka Basalts, form the celebrated Batoka Gorge, through which the pent-up waters of the Zambesi course after their giant tumble over the Victoria Falls. It is a crack in the basalts which has given rise to the Falls themselves.

Valuable Permian coalfields also occur in the Transvaal and Natal.

Great Lava Outpourings in Brazil.

During the Trias, or possibly a little later, an enormous area of Brazil and the Parana basin was flooded, time and time again, by horizontal sheets of lava; these, also, were ejected from fissures, with few or no volcanic explosions. Their remnants cover an area of over 300,000 square miles, to an average depth of 1,000 feet (136). The world can show but few volcanic episodes of such a magnitude.

Paucity of Fossils (Plate 54).

The fossils that have so far been discovered in the rocks of these two great ages, Permian and Trias, bear no relation whatever to their importance. They are nearly everywhere meagre; over a great part of the globe they are excessively rare. Where marine, they tell us of only slight and gradual

Fig. 6.—Diagram of a cycad (after Berry).

changes from the time of the Coal Age, and although the marine deposits entombed numerous sea urchins, sponges, corals and small cephalopods, they are, we fear, not of much interest to the general reader. Where terrestrial, the fossils of these ages are usually footprints and bones of lizards, and the fragmentary remains of plants; most of these can be disposed of in a passing glance. Of the plants we have spoken already. Their most noteworthy features, perhaps, are the disappearance, step by step, of the gigantic lycopods and Sigillaria of the Coal

Age, and the growth of coniferous trees bearing true cones; also the beginning of the young palms (cycads: Fig. 5), which were destined shortly after to people the Earth in great abundance. These beautiful plants had very short stems or trunks, and their leaves resembled those of ferns both in rough outline and in their property of unrolling outwards. (*See also* Plates 52, 53.) Their modern range is extremely restricted.

EARLIEST MAMMALS (Plate 54, 3).

To the land animals we will devote rather more time. The Trias would always be noteworthy to students of evolution, if for no other reason than because in it are found the earliest known mammals, the highest class of vertebrates. Mammals, as a whole, are distinguished from other vertebrates in two ways: firstly, some part of the body, at some time of life, is always provided with hairs; secondly, the young are nourished for a shorter or longer period by a special fluid—the milk—which the mother secretes in special glands known as mammary glands: hence the name "mammals." The oldest mammal, as one would expect, was of a humble and primitive kind; being only a small ally, named Microlestes, of the banded anteater of Australia. Only halves of the lower jaw and occasional teeth of these animals have as yet been unearthed; and they almost certainly played a small and inconspicuous part in the world. An early ally of the kangaroo rat, a marsupial, was another humble mammal of these times. The existence, even to-day, of marsupials, is a unique instance of the survival of a primitive mammal structure through many eons of time. The organisation of the marsupials, compared to that of other mammals, is distinctly primitive. "There is no placenta or vascular communication between mother and fœtus, parturition taking place before any necessity arises for such an arrangement.

As the young are born in such an imperfect state of development, special arrangements are required to secure their existence. When born, they are therefore, in the great majority of cases, transformed by the mother to a peculiar pouch formed by a folding of the integument of the abdomen. This pouch is known as the marsupium, and gives the name to the order. Within the marsupium are the nipples" (137).

Absence of Birds.

Of birds, there is no certain trace during this age, although they may have been in existence towards its close. If there were any, they were so strange and bat-like or reptilian in appearance as almost to belie the name of birds.

Lizard-like Reptiles; Labyrinthodonts.

We find, however, no lack of reptiles; though they were generally built on one model, the lizards (Plates 48, 51). Now, one great characteristic of a reptile is, of course, that it is cold-blooded. This is due to the fact that the circulations of arterial blood and venous blood are always directly connected together, instead of, as in warm-blooded animals, being separate. Another characteristic is that the lower jaw articulates with the skull by means of a bone (the quadrate bone) placed very far back, so that the mouth opening becomes relatively gigantic, sometimes extending beyond the base of the skull. South Africa, and especially Natal, has yielded a number of curious dog-toothed reptiles (Cynodonts) which are believed by Osborn and others to mark a transitional stage to the mammals.

One of the oldest of reptiles is found in middle Permian rocks. It was a salamandriform lizard, attaining a length of about 4 feet; its name Proterosaurus (saurus means merely lizard). It was followed by a large variety of other reptiles, the most important being the Dinosaurs, of which more anon: early Dinosaurs occur in the Trias of Europe and South Africa. A primitive Texas lizard, Varanops, of Permian time could well be ancestral to lizards, alligators, and dinosaurs. The Labyrinthodonts (pp. 163–4) had also developed considerably since Carboniferous times; and these curious newt-like amphibians now inhabited every continent. Many of these animals are known only from their footprints, left in the mud, baked in the sun, and buried by the next layer of slime (Plate 51, *4*, *5*); many others have left more or less fragmentary remains, mostly skulls. Some of the latter have a curious "death's-head" aspect, due to the enormous eye-sockets; this probably gave them a crocodilian appearance.

One of the most curious of these creatures was Cheirotherium, which had singularly hand-like feet, the under-surfaces whereof possessed fleshy pads, the claws being retractile at the animal's will. It was of considerable size, since it had a stride of 2 feet 8 inches (138).

The fore legs of many Labyrinthodonts made practically no impression, even on the soft muddy flats whereon they dwelt. This indicates that the creatures walked on their hind legs, only using the others to steady themselves when bending down to drink or to feed. In the next age we shall find the same thing in immensely larger creatures, of ferocious and terrible aspect.

Some of the Triassic footprints are as much as 22 inches long by 12 inches wide, and the feet that made them must have belonged to no insignificant lizards. Footprints are found in large numbers in many places, sometimes so clearly preserved that the imprint of the toenail comes out. The Connecticut Valley was a celebrated haunt of the old reptiles; Storeton, in Cheshire, was another.

A curious reptile of these days, which frequented our own islands, is known as Rhynchosaurus (Plate 51, *1*, *2*). It had an elongated, triangular, flat-roofed skull, with a long, down-curving beak and very large eyes; and the hind limbs were the longer. Its skin was probably an armour of horny scales, very small, and irregularly shaped. It probably lived mainly in the water, hiding among the reeds and swamps.

THE PHYTOSAURS.

Another singular group of reptiles were the Phytosaurs of North America; they lived partly on land, but mainly in the water. Their mode of existence led to the development of a snout-like prolongation of the face, possibly as a rake wherewith the animal sorted out worms and other soft-bodied creatures in the mud. Other forms had the nostrils raised on a considerable prominence, possibly due to the animal's habit of lying in wait for its prey under water, with nothing but its breathing apparatus above the surface. The teeth of this type were suitable for tearing large vertebrates. It has the handy name of Machæroprosopus (139).

CROCODILES.

Next to the lizards come the crocodiles, whose bodily make-up shows a distinct affinity to that of fishes, and whose main distinction from lizards is the possession of a partly bony outer skeleton, in addition to the ordinary scales. Their teeth, also, which are usually sharp and fang-like, are planted in distinct sockets; the teeth of lizards are not. One of the Triassic crocodiles (Stagonolepis) resembled the modern cayman in general form. Others (Thecodont- and Palæosaurus) were indeed natural curiosities—a sort of cross between a crocodile, a lizard and a dinosaur.

Marine Reptiles.

Marine reptiles, though not as yet numerous, foreshadowed the coming of the gigantic Ichthyosaurs and Plesiosaurs of the next age. Their limbs were converted into powerful swimming paddles, their necks elongated, and their eyes very greatly enlarged. We shall meet them at close quarters shortly.

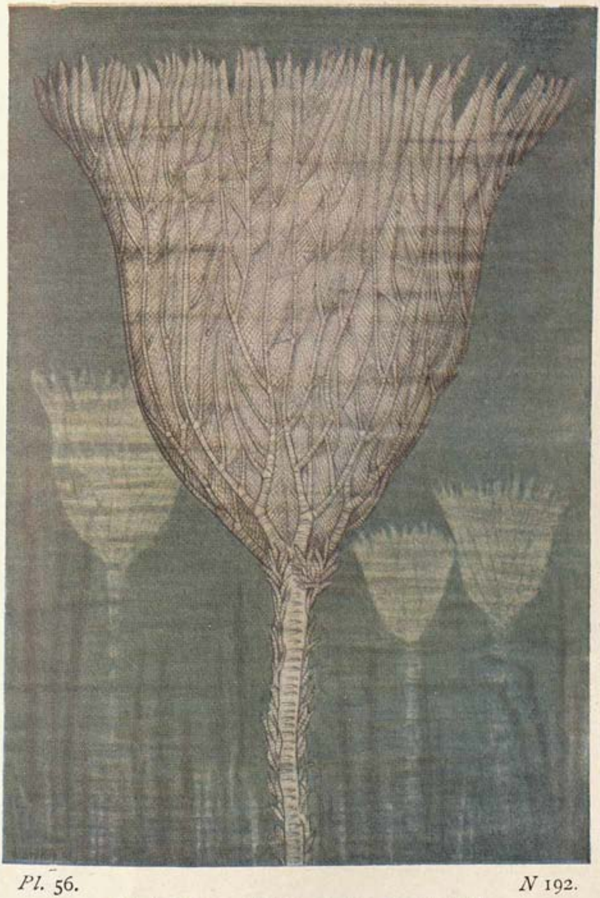
Anomodonts.

A strange group of reptiles, the Anomodonts (Plate 57), must close this list.

They had a body like a lizard, but jaws like a turtle, ending in a kind of beak that was probably sheathed in horn. "Sometimes the mouth appears to have been wholly destitute of teeth; but in other cases, there was a single pair of teeth implanted in the upper jaw . . . assuming a character of great tusks. . . . The animal seems to have been organised for terrestrial progression" (140). These animals, which have several mammalian affinities, are now known from Russia, the United States, South Africa, and India.

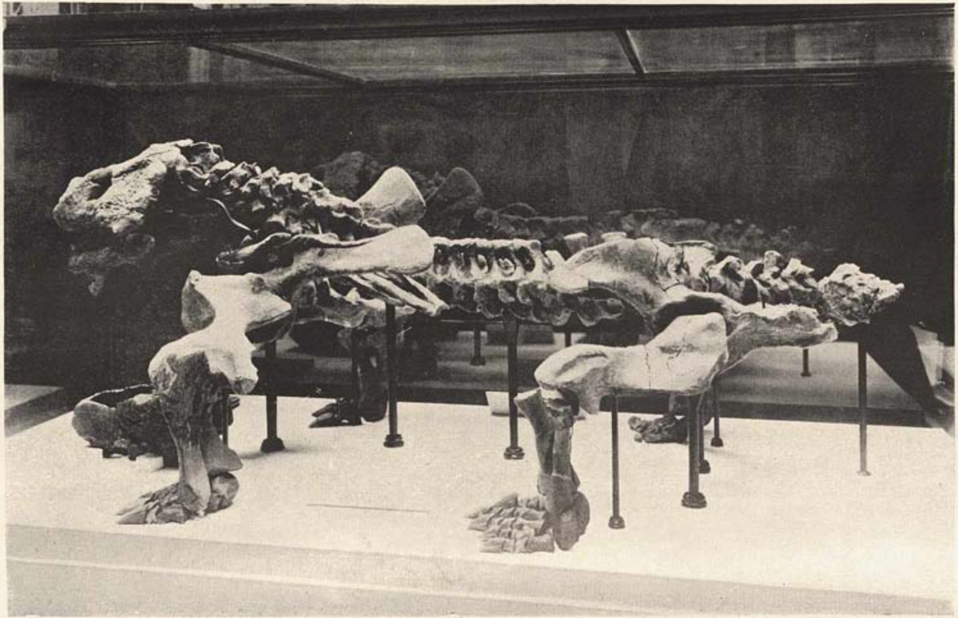
An Early Apus.

Finally, we have a very rare but otherwise unexceptionable creature to mention—Apus, a primitive existing freshwater crustacean, a representative of which has been found in the Permian of Oklahoma, and a single other specimen in the Trias of the Vosges (141). In our days, Apus only appears at long intervals, usually after tens of years, during which its eggs have lain buried in the dried mud of roads, ditches and pools, and exposed to heat and cold. Once development starts, however, it goes on with a rush; the animal attains its full size of 3 to 5 inches within a fortnight; lays an



Pl. 56. *N* 192.

Pentacrinus. A Jurassic Sea Lily (p. 196).



Pl. 57. *N* 193.

Pariasaurus.

The helmet-cheek Lizard. A massive animal, 8 to 10 feet long, with legs like an antique chair (p. 192).

enormous number of eggs, and dies. It has 52 pairs of feet. So far as superficial appearances go, there is no difference between the modern and the ancient forms. Perhaps, while all the rest of the organised world has been marching forward, Apus has been a real Rip Van Winkle, very much asleep.

CHAPTER VIII.

The Age of Reptiles (*Jurassic*).

THE "MIDDLE AGES" OF EARTH HISTORY.

IN its major divisions, the history of the Earth bears a passing resemblance to that of civilised man. As human history is divided into Ancient, Early Christian, Mediæval and Modern, so, in a similar manner, we may divide the terrestrial story into Ancient—represented by the pre-Cambrian rocks; less Ancient—the events from the beginning of the Cambrian to the end of the Permian; Mediæval—from the commencement of the Trias to the close of the Chalk Age; and Modern (more or less), comprising all the rest. The portions of time which each epoch comprises are not unfairly represented on this scale either. It follows from the above that, notwithstanding all the innumerable changes which we have summarised in previous chapters, our narrative has only just entered upon its "Middle Ages."

In the corresponding period of human story, tales of chivalry and romance gild up what was really a most barbaric age. Similarly, in the Jurassic period of the Earth's story, the strange monsters of land and deep lend a charm and unreality to an epoch which was otherwise destitute of any very striking or unusual events. This will necessitate our devoting very much more space to the inhabitants of the Jurassic world than to their habitat.

Origin of the Name "Jurassic."

The period owes its name to the splendid development of its rocks in the Jura Mountains (Plate 55, c). It was essentially a period of quiet development of animal life amid surroundings which constantly changed, but generally at so slow a rate as to be imperceptible. The climate or the topography (or both) offered no scope whatever for mammals to evolve, and they remained almost stationary. Reptiles, on the other hand, passed through some marvellous transformations.

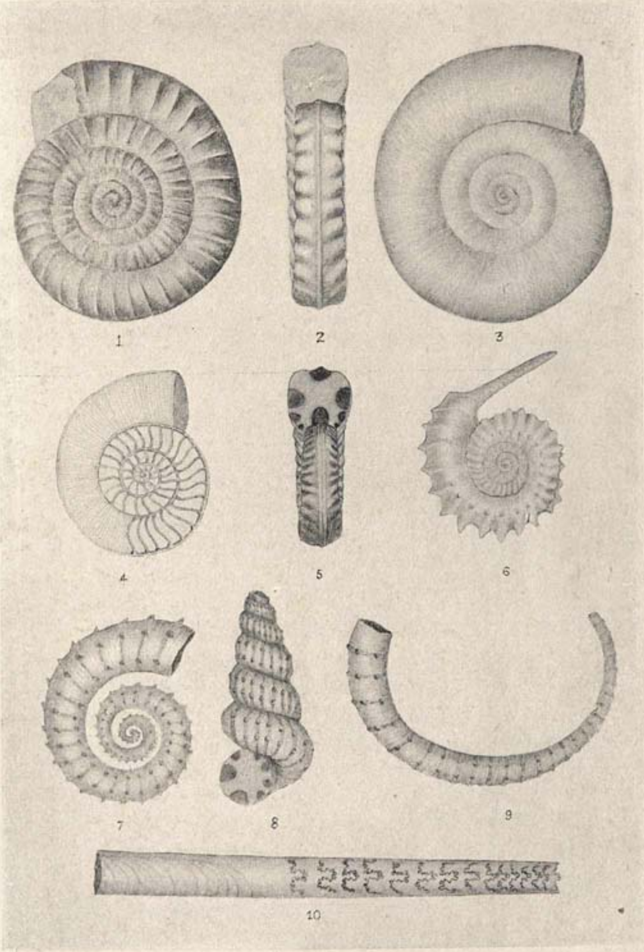
The Lias Sea.

The end of the Trias found a large part of Britain sinking beneath a great incursion of marine waters, known as the Lias Sea. In the main, this subsidence was slow and insensible; but on one or two occasions it was greatly accelerated, large areas of land being depressed so rapidly that their inhabitants had not time to escape, and were exterminated. The remains of small mammals, mingled with those of plants and fishes, form well-marked "bone-beds"; and the fact that these singular deposits are not confined to this country, but extend over a large part of Europe, seems to prove that they were brought about by true catastrophes, possibly the exact reverse of an operation which in the present century lifted a part of the Alaska coast bodily 47 feet above the waves.

As the sea lapped over first one county and then another, it gradually divided Britain up into groups of islands. Wales and Hereford formed one such insular tract. Dartmoor and the other high elevations of Devon and Cornwall, the hilly region of Derbyshire and the Cumbrian Mountains, probably formed others. The islands lay, on the whole, to the north-west of a line running from Axminster to Whitby; to the east of this line was open water. The southern deposits now form the magnificent cliff section from Lyme Regis to Bridport (Plate 55, A). At the same time, parts of Southern Scotland and of the Highlands were submerged; and on the west coast, the Island of Skye was also beneath the waves.

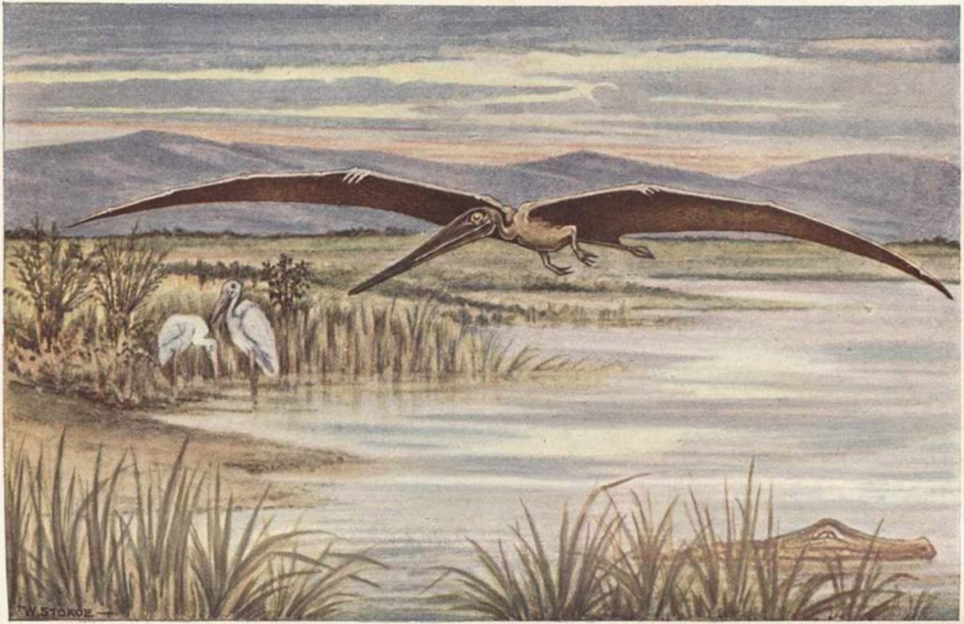
Variety of Life in the Lias Sea.

The submergence continued until the sea was from 60 to 100 fathoms deep; and on the bottom a great mass of bluish clay and impure limestone, the Lias Clay, slowly accumulated around the remains of countless molluscs, corals and other organisms. In favoured places, sea lilies, of an infinitely more beautiful aspect than any of their predecessors (Plate 56), waved their tufted heads from exceedingly long and slender stalks; sometimes the latter attained as much as 50 feet. In the shallower waters, reefs of living coral bathed in the surf. Everywhere small cephalopods, called Ammonites (Plate 58), together with oysters and other shells, were to be found in myriads. In the open ocean, a gigantic lizard, very predaceous and cruel, the celebrated Ichthyosaur (Plate 60), roamed at will, fearlessly attacking all and sundry; while further inshore, a smaller but still formidable monster, the Plesiosaur (Plate 63), preyed on the minor denizens of the deep. In the islands and over the lagoons, flying lizards, huge in size and horridly bat-like in aspect, whizzed through the air, their wings sometimes having a spread of 8 or 10 feet (Plate 59). The islands themselves were, in general, crowded with vegetation to the water's edge, and with the life which vegetation feeds and hides. Coniferous trees, cycads or young palms, ferns, weeds and the earliest known true grasses, formed a green paradise in which developed the small marsupial animals, of kangaroo-rat aspect and insect-eating habits; here, also, were swarms of insects of many different kinds. About the same time, too, true flies, the plague of humanity, came into being; but butterflies



Pl. 58. *N* 196.

Ammonites (p 196). 1, 2. A. Raricostatum. 3. A. Planorbis. 4. 5. A. Obtusum. 6. A. Jason. 7. Crioceras. 8. Turrilites. 9. Toxoceras. 10. Baculites.



Pl. 59. *O* 197

A Pterodactyle, or Flying Lizard.

Not uncommon in Jurassic and Cretaceous times, these hideous creatures varied in size from a few inches to 28 ft. (pp. 196, 233). The one figured (Rhamphorhynchus) inhabited Bavaria.

and moths were as yet unknown, and their absence emphasises the lack of flowers in the world.

The bed of the Lias Sea sank, as usual, beneath its ever-growing load of detritus, but at unequal rates in different parts. In the earlier stages, the greatest depression was in the south, in Dorsetshire. Later, the movement, though still downwards there became exceedingly slight; but it grew progressively greater towards the north, until on the Yorkshire coast it reached a maximum. It was also fairly rapid in those parts. For example, in the clays near Whitby have been found the petrified trunks of coniferous trees, which had not time to decay ere they were submerged. Another famous fossil "forest" occurs at Lulworth, Dorset (Plate 64).

Climate of Britain at this Time.

The climate at this time was probably tropical, though tempered by the great expanse of water. The dryness, as well as the cold, of the Trias had gone; and we may reasonably infer that the plentiful vegetation of the islands was due, in the main, to the regular warmth and frequent showers which their insular situation would imply. An interesting sidelight on the climatic conditions, indicating both humidity and warmth, is shed by the extraordinary swarms of winged insects; whose remains, swept doubtless by wind and storm into the lagoons and meres, form distinct layers in the rocks.

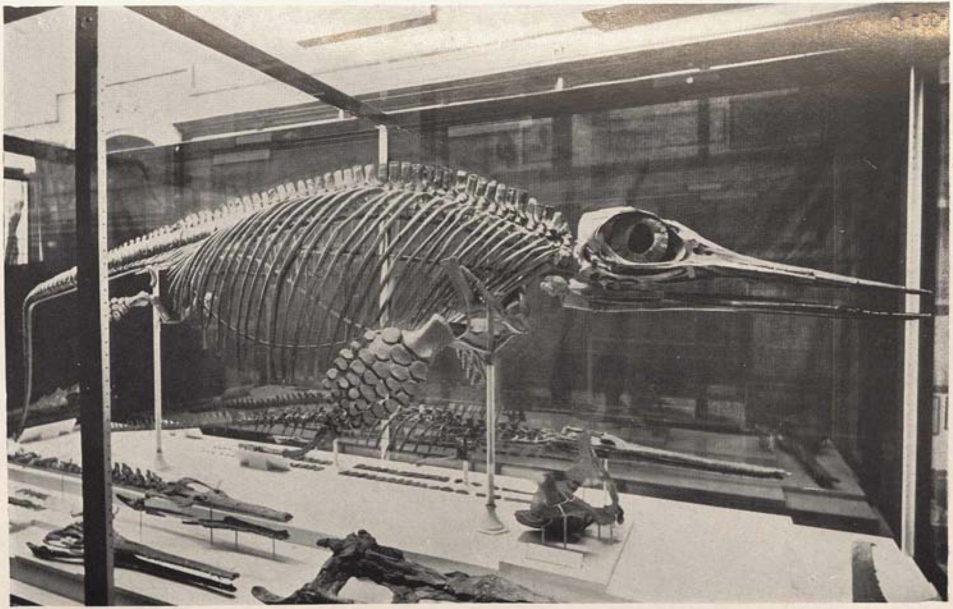
The Oolites.

In England, as elsewhere, the Liassic Sea was followed by the Oolitic; in the waters of which, whitish limestones and building stones, composed of small egglike or oolitic grains about the size of a pin's head, were the predominating deposits. From this point to the end of the Jurassic there were many quiet changes, at which we can only glance in passing.

SUBMERGENCES IN SOUTHERN BRITAIN.

In the south of England, the rather muddy waters of the Lias Sea were separated from the clearer and occasionally deeper ones of the Oolites by a short interval, when sandy shoals ran from Bridport, by way of Yeovil and Midford, to the Cotteswold Hills. A similar shoal existed near Oxford; but farther north-west, towards Lincolnshire, stretched deeper water. Later in the age this area became land, the borders of which extended northwards at least as far as North Yorkshire; and hereabouts tide-level marshes, the burial ground of masses of decaying vegetation, extended for possibly some hundreds of square miles. Thus, we find plant remains in Northamptonshire, bands of coal in Yorkshire, and a bed of coal as much as 4 feet thick in Sutherland—all obviously the growth of ages. But these conditions did not invade the Midlands or the Thames Valley, where alternations of shallow and deep water continued their even course without a break. In parts of this large area, oyster reefs flourished in great profusion; only to be buried and destroyed by the inexorable law of changing environment. So numerous were the oysters of that time, that their shells have often been used for paving roads in Lincolnshire (142).

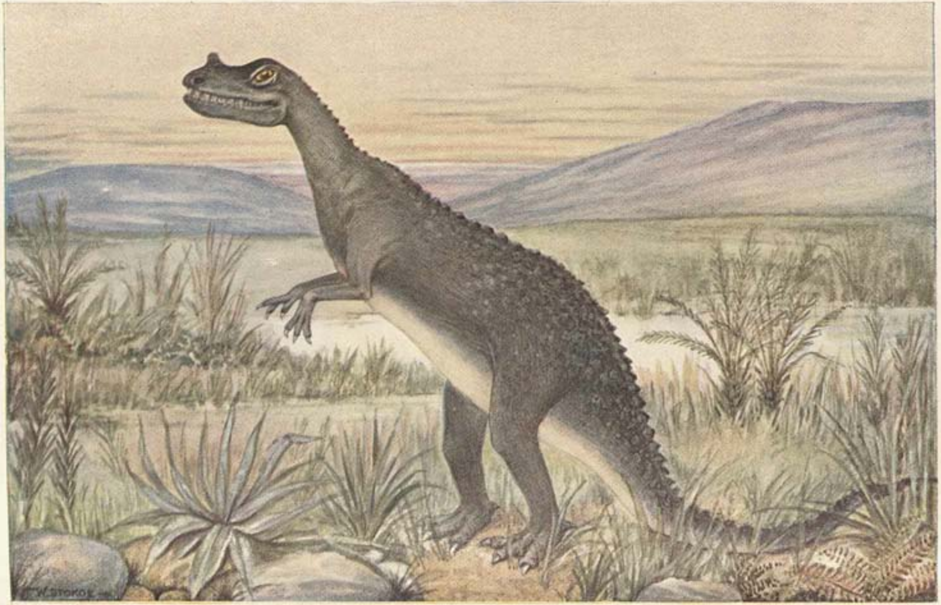
A strange land must ours have been in this age! In the marshes, and upon the lands behind them, gigantic reptiles, far surpassing in size and ferocity anything yet seen on the Earth, had their haunts; while some kinds fed on the abundant pasture, others, smaller, but much more strongly built, preyed on their fellows. Mammals continued to be small and insignificant; and they must have felt so whenever they encountered their gigantic contemporaries, which ranged in size up to 40 or 50 feet. In the shore lagoons, too, terror was not wanting; for the place of the Plesiosaur had been taken by an extraordinary lizard, the Cetiosaur, a nightmare of a creature some 50 feet long. When, from the window of a railway carriage or the



Pl. 60. *O* 198.

Ichthyosaurus.

The most powerful sea-monster of early Jurassic times, this Fish-Lizard abounded at Lyme Regis (p. 212).



Pl. 61. *O* 199.

Ceratosaurus.

This fearsome monster, once common in North America, was sufficiently powerful to slaughter the huge but otherwise defenceless flesh-eating Dinosaurs. (p. 206).

seat of a car, one surveys the great stretches of wheat and pasture land, the old thatched houses and farms, the stately mansions, and the silent, dreamy canals of this beautiful land, one cannot help commenting on the incongruity between its past and present aspect.

As we have said, the western counties were all this while under water. The main bed of Oolitic rock which was laid down there, forms the well-known Bath building stone. At a later stage in the same age, Nature was busy in constructing an equally good building material farther south—to wit, the Portland stone. These products have the valuable property of being comparatively soft when quarried, but of hardening on exposure to the air.

A Much-changing Country.

Change succeeded change with bewildering frequency—shallow seas, deep seas, coral islands, mudbanks and shorelines. The sum total of it all was, that the south and south-east of England, after fluctuating for a considerable time between estuarine and marine conditions, became solidly attached to a great land mass which had arisen over the area of the North Sea, and which slowly cast arms about an Anglo-French basin of considerable size. This elevation of the land over most of Britain takes us into a new epoch.

The Jurassic in France.

Turning now to the continent of Europe, we find that in France, as in England, the terrestrial conditions of the Trias were terminated by the incursion of the Lias Seas. Paris was the heart of the submergence. Franche-Comté, Berry, Bourgogne, the Upper Marne and the Jura, the Rhone Basin about Lyons, Provence, Languedoc, Poitou, Vendée and

Normandy, all were at one time or another obliterated. Farther north it was the same. The site of the Ardennes was open water, and Luxembourg formed a large gulf; marshes or rivers of some magnitude drained into the latter, for drifted plants were frequently washed into it and buried there.

Conditions in Germany. Appearance of Beetles.

In Germany, again, Swabia affords excellent examples of the sudden destruction of life during the widespread sinking in Rhætic times; while in Silesia, the Triassic deserts were replaced by not less desolate Rhætic salt marshes, and the latter by open sea. The site of the Alps was still well below sea-level; for example, in the Canton of Vaud, fossil oyster beds of this age have been found—a striking example of geological changes which anyone can understand.

Leaving Germany for a moment, we find that in Scandinavia the Rhætic milestone is better marked than elsewhere. This part of the Earth appears to have been a centre of freshwater—probably lacustrine—accumulations; and under favourable conditions of climate and soil a large and rich flora flourished, much of which has come down to us as fossils. It is noteworthy that beetles here make their appearance for the first time. After a long spell of these freshwater conditions, the Liassic Seas broke in here also; and the later part of the age was as truly marine as the earlier had been terrestrial.

Coal Formation in the Carpathians.

Meanwhile, all the incidents of a minor Coal Age were being enacted far to the south, over the site of the Carpathian Mountains. There, marshes of similar aspect to those which fronted eastern Britain had their being. They persisted, however, for a very much longer period, with all the complicated phenomena of slight submergences and repeated delta building; until no less than twenty-five beds of coal, making a total thickness of 85 feet, with important iron ore beds, were formed. The nature of these great marshes or shoreline forests is unfortunately indeterminable, because the plant remains are fragmentary and decomposed. It is probable, however, that it did not differ greatly from that of the rest of Europe, except in its greater abundance.

UNEVENTFUL CHARACTER OF THE AGE.

As the Jurassic period wore on, the great seas of the Lias underwent numerous constrictions, but all were of the same quiet and uneventful nature. The fires of Hades seemed extinct in Europe. Sea water and corals, marshy shores, palmettos, sunshine and abundant rain, gave to the Earth more of the appearance of a paradise than had been its lot since Silurian times. It was under these conditions that more pieces of the modern mosaic of the Earth's surface were put into place. Thus, in the middle of the Oolitic events, the central plateau of France, which had been an island through many vicissitudes of past epochs, was united, for the first time, to the Vosges, on the one hand, and to La Vendee on the other: a notable beginning to the continent which finally blotted out the Jurassic seas altogether.

THE SLATES OF SOLENHOFEN.

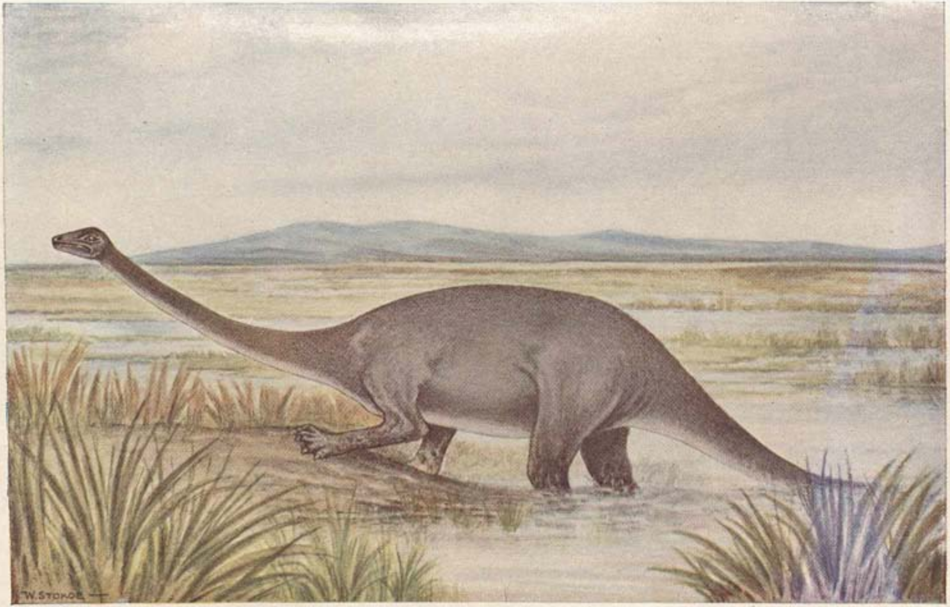
We cannot leave West Central Europe without referring to the celebrated Lithographic Slates of Solenhofen, in Bavaria; a mass of rock which appears to have been deposited in a lake or else an unusually peaceful lagoon. This rock has yielded an extraordinarily rich and varied assemblage of organic remains, from jellyfish to flying lizards. Among them is the skeleton of the earliest known true bird, Archæopteryx (Plate 68, *1*); there are also numerous fishes, and nearly fifty species of small mammals. Flies, spiders, crustaceans, naked cuttlefish with their inkbags complete, reptiles and molluscs, all have representatives in this motley graveyard.

THE MEDITERRANEAN THEN MUCH SWOLLEN.

Throughout the age, the great marine basin of the Mediterranean continued unchanged. It was very much larger than at present. One of its arms extended far up the valley of the Rhone, and a bay covered the site of the Cevennes. In Italy, too, the sea extended over Milan; the Swiss Alps, Savoy, Lake Garda and the Central Apennines, all were a part of the swollen ocean. Yet another arm seems to have stretched across the Hungarian plain, and to have covered parts of Galicia and Transylvania. It trespassed on the Algerian shore; and it claimed for its own a large part of Southern Spain. It was deep, quiet and clear—essentially an area where limestone might be deposited. At certain times it was strewn with coral reefs, and altogether it wore the appearance and owned the charm of the Southern Seas. When the age closed, the creation of the continent on the north seems to have markedly cooled the climate; for we find the warm-water creatures receding farther and farther towards the Equator.

RUSSIA.

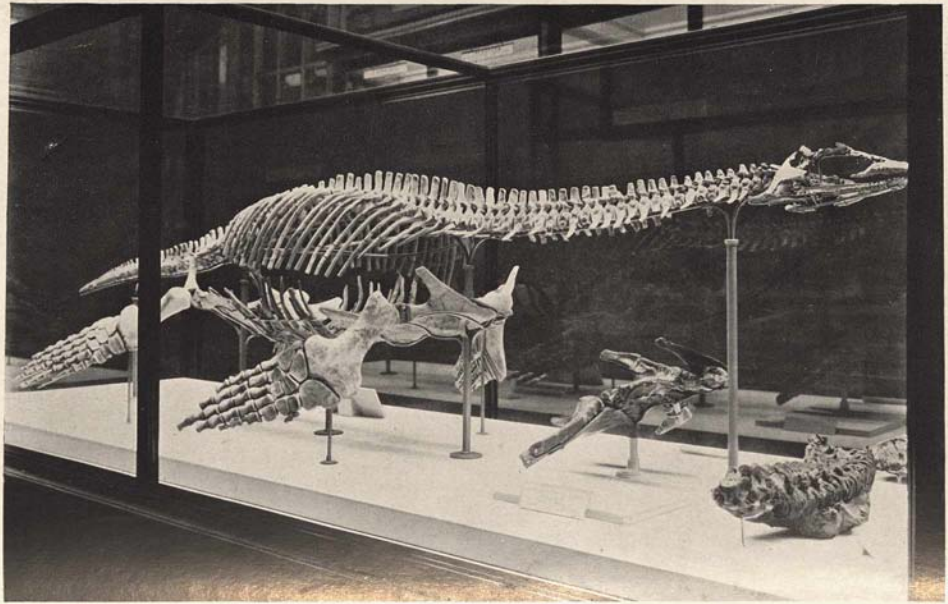
Russia, in these times, differed both from the open sea of the Mediterranean and the islet-dotted one of France and Britain. It was, in the main—and the same remark applies to Asiatic Russia also—a vast, lowlying, ill-drained waste, choked up with morasses, and strangely reminiscent, in many respects,



Pl. 62. *O* 202.

Brontosaurus.

The Thunder Lizard, as helpless as it was huge (p. 209). Its British ally, Cetiosaurus, was 60 feet long, and frequented Oxfordshire.



Pl. 63. *O* 203.

Plesiosaurus.

The Sea Dragon. Though less powerful than Ichthyosaurus (Pl. 60), it was not to be despised (p. 212). The bones of the paddle are beautifully shown in the photograph.

of the Coal Age. Numerous coal beds, some of them workable, were, indeed, formed.

Plant Life of the Age.

It is a signal instance of the uniformity of climate at this time, that the same kinds of plants existed at Ando, in Norway, in far Spitzbergen, in the Petchora and Tungusk districts, in the Altai, in the extreme north of Siberia, in the Amour Basin and Japan, and even in the Antarctic wilderness of Graham Land. They were all tropical or sub-tropical; if a paradise, the Earth was certainly a perspiring one. The ferns belong, for the most part, to species inhabiting high and dry localities; they have hard skins and meagre fronds. Some of the palmettos, which were extraordinarily abundant, favoured low and wet places, others a dry habitat. The beautiful maiden-hair tree, sacred in Japan, flourished in a few favoured places. Araucarian pines and dark, brooding cypress trees formed groves, and perhaps forests, wherein the great reptiles may have occasionally wandered, and where the anteaters certainly dwelt; but the gorgeous flowers which, in clearings in a modern forest, occasionally delight the traveller's eye—the noisy chatter of song-birds and the gibberings of monkeys—were conspicuous by their absence. Tall ancestors of the great Sequoia or bigwood tree were not infrequently to be found; but these, in common with most of the plants of the time, were probably smaller than their modern representatives.

Gondwanaland.

Throughout the Jurassic, the sea continued to nibble at the shores of Gondwanaland; and towards its close there was, in places, intense volcanic activity. In the Oman region, in the Persian Gulf, there was, in particular, a huge outpouring of lavas, accompanied by the intrusion between the bedded rocks of great sheets or sills of molten rock. This demonstration ended, in the dawn of the next age, with an uplift of the area (143). On the Afghan and Rajputana coasts of Gondwanaland there were several oscillations of level during the age; and farther north, in Spiti, the originally deep seas gradually shallowed as Cretaceous times drew near. On the other side of the land, the continental conditions which had long prevailed in Yunnan extended southward over the Shan States; resulting in the spread of vast marshes and flood plains over the whole eastern border of Gondwanaland, from north-east China to the confines of Burma. As the land rose, so the marshes were gradually drained away; in the next age, the whole area was high and dry. All this part of the world has been continuously above the sea ever since (144).

Great masses of Lias marine rocks were laid down in Western Australia, but the rest of the continent remained dry land.

Mountain Building in North America.

Finally, we find in North America still another aspect of the Jurassic epoch—to wit, the creation of great mountain chains; for the close of the epoch marked the elevation of the western half of the Cordilleras, and especially of the Sierra Nevada—the first really great movement in those regions since pre-Cambrian times. Much of the Great Plains of the United States was once more temporarily invaded by sea water; and at the very close of the time, these interior seas washed the eastern base of the Cordillera. The climate here seems to have been unusually wet; for thousands of cubic miles of rock were rapidly worn away from the new-formed mountains, and the tops of the molten masses which, by forcing up the bedded rocks, had created the mountains, and which were but newly cooled, were exposed to atmospheric wear and tear.

Elevation of the Coast Range.

At the same time, the great Coast Range of British Columbia had its birth by the elevation of huge domes of molten rock into the bedded rocks above. So great has been the destructive force of frost and rain since then, that only fragments of the latter remain, "roof pendants" on the top of the solidified domes. The latter, though varying widely in composition, are all uniformly coarse-grained or granitoid. They did not assume their present aspect during any one advance, but by repeated efforts at irregular intervals. What was the driving motive which forced them up is, as we mentioned at the commencement of this work, wholly unknown. The exact order of events, also, is far from clear, owing to all fossils having been destroyed by the heat and pressure which were applied to their rocky tombs. During the periods of quiet which separated the different efforts, the molten rock at the margins of the domes solidified to a certain depth; then a new demand for relief of stress caused the still molten interior parts to rupture the crust which had formed, and again attack the bedded rocks above; while in every crevice sheet-like fingers of irregular outline forced their way (145). In a word, it was the old story of the Laurentian mountain building all over again. Nature may not repeat herself in detail; but in plan, her operations on the Earth's crust are singularly uniform. I am very conscious that a certain tedium cannot be avoided, because in every chapter I have to tell the same story over and over again. It is, therefore, with relief that I hasten to divert the reader with a few notes on the bizarre creatures of the Jurassic epoch.

The Dinosaurs.

First and foremost, the Dinosaurs, or Terrible Lizards, the lords of the Earth in that time, must claim our attention.

They originated in the Trias, but it is not until Jurassic times that they attain the gigantic dimensions which have for so long been the jest of buffoons and the wonder of the intelligent. At the same time, they were not all large. Some, in fact, were quite small creatures; and, except for their habits, fit companions for the small marsupials which lived along with them. They may be divided into two great classes —those which lived on plants, and those which were carnivorous; of these, the former were by far the larger in size, but the latter infinitely more formidable. Some, huge and unwieldy, clad in great coats of mail, and armed with plates thick enough to clothe the sides of a battleship, were grotesque in their very greatness; others, light and graceful, with pneumatic chambers in their bones, were so like birds that only a comparative anatomist could tell one from the other. Although many specimens have been found in Europe and elsewhere, these creatures were best preserved in North America. In the regions at the base of the Rocky Mountains, they flourished during the later part of the age, and their bones have been found in vast numbers there. Other interesting finds have been made in East Africa, Patagonia and Mongolia.

FLESH-EATING DINOSAURS.

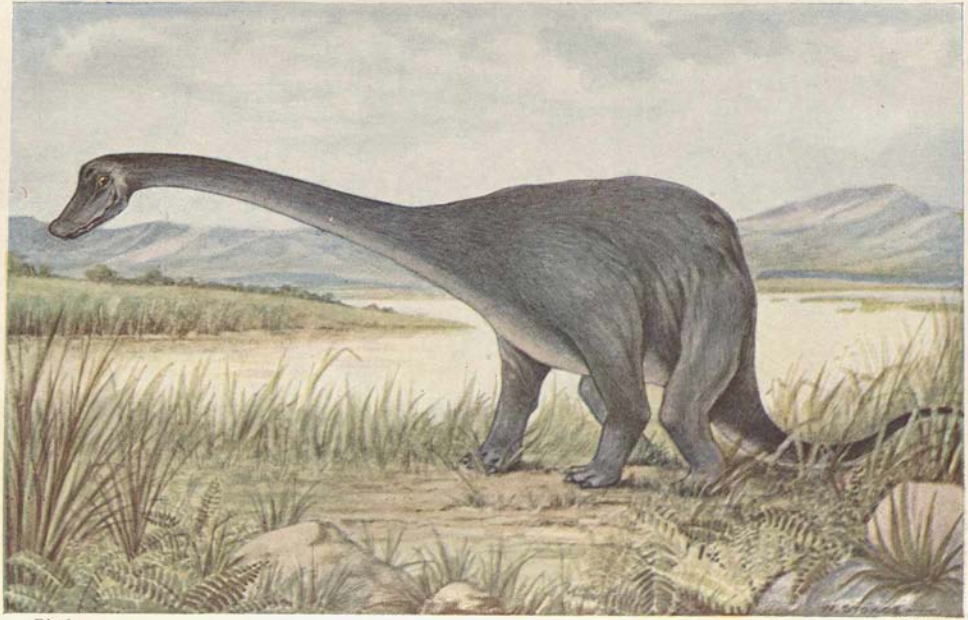
Taking the flesh-eaters first, the smallest Dinosaur, known at Hallopus (leaping-foot), was about the size of a rabbit. Its hind limbs were especially adapted for leaping, and are more slender than in almost any known reptile (146). Its immediate successor seems to have been an animal called Cælurus, in size between a fox and a wolf, and having pneumatic limbs: *i.e.* its bones contained air sacs which made them exceedingly light and bird-like.

CERATOSAURUS.

Of the larger forms, Ceratosaurus (147) (Plate 61), the horned lizard, had a horn on its skull, after the manner of the modern

Pl. 64. *O* 206.

Fossil Forest, Lulworth, Dorset, of Jurassic Age (p. 197).



Pl. 65. *O* 207.

Diplodocus.

80 feet long; very weak laterally: with a brain no bigger than a hen's egg (p. 209).

rhinoceros. Nevertheless, the bones of its pelvis were anchylosed together, or fused into one, like those of a bird. The head was very large in relation to the rest of the animal; and when seen from above, the skull resembled in general appearance that of an alligator. The horn, which was high and powerful, was peculiar to the Ceratosaurs, and is not found in any other carnivorous Dinosaurs. The animal had sixty large and powerful teeth—a sure indicator of its ferocious nature. It had a high, thin tail, well adapted to swimming; and its brain was larger than that of most Dinosaurs. It may have stood, in wet regions, habitually on its hind legs, in the manner in which dragons are usually depicted as waiting for their prey. As it was 12 feet high and over 20 feet long, it would have taxed the skill of any St. George to defeat it!

Tyrannosaurus and Others.

Other large predaceous Dinosaurs were Tyrannosaurus (Plate 1), Creosaurus, Megalosaurus and Labrosaurus, all inveterate enemies of the herbivorous kinds. All had fearful jaws, sharp cutting teeth and a long flexible neck. The fore limbs were quite small, and the feet were armed with strong claws for seizing living prey. The hind limbs, on the other hand, were distinctly hefty, and the animals used them alone in locomotion. Tyrannosaurus, by the way, is the largest flesh-eating Dinosaur known. It has strong analogies with a form which was very common in Europe—to wit, Megalosaurus.

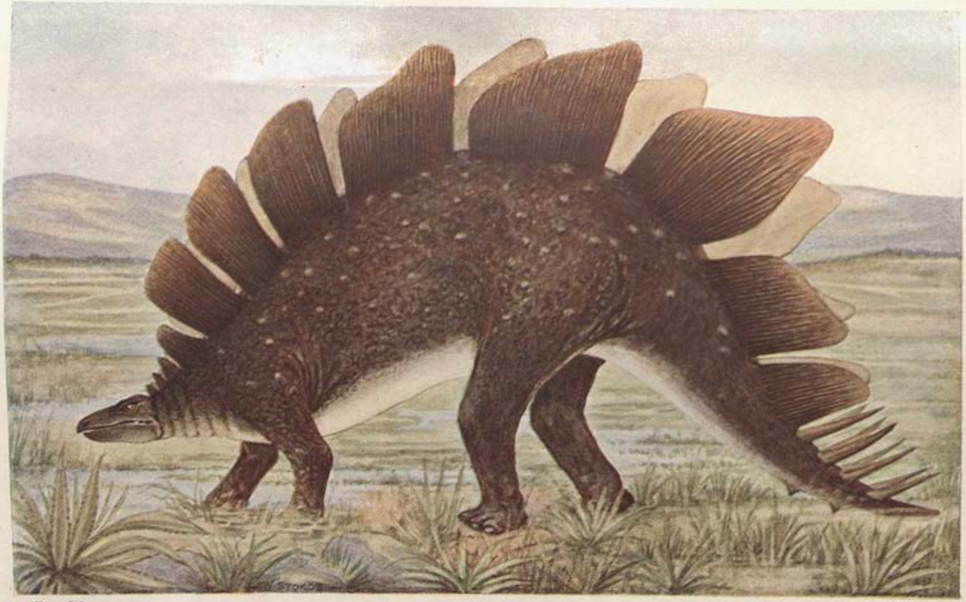
Plant-eating Dinosaurs.

We come now to the less ferocious but much more bulky plant-eating Dinosaurs. Professor O. C. Marsh, one of the greatest authorities on this subject, found the first American specimen near Lake Como in Wyoming, in 1868; since when

Plated Lizards.

We now come to a group of reptiles of a far more terrifying aspect—to wit, the Plated Lizards (Stegosaurs). In these, the skull was long and slender, and the teeth were small. The brain must have been trifling—compared with that of an alligator, only one-hundredth as large, if the weight of the two animals be considered (149). Although it walked on all four feet, the hind limbs of the Stegosaur were longer than the fore limbs (Plate 66). The most singular characteristic of this creature was its series of spines, some of great size and power, and the many bony plates which were so well fitted for protecting it against assault. Some of the latter were more than 3 feet in diameter, while the spines were sometimes over 2 feet long. The various species, and perhaps the sexes also, differed in the form, size and number of these spines and plates. "The skull was evidently covered above with a comparatively soft integument. The throat and neck below were well protected by small rounded and flattened ossicles having a regular arrangement in the thick skin . . . the upper portion of the neck, back of the skull, was protected by plates arranged in pairs on either side. These plates increased in size further back, and thus the trunk was shielded from injury. From the pelvic region backwards, a series of huge plates stood upright along the median line (of the back), gradually diminishing in size to about the middle of the tail" (150).

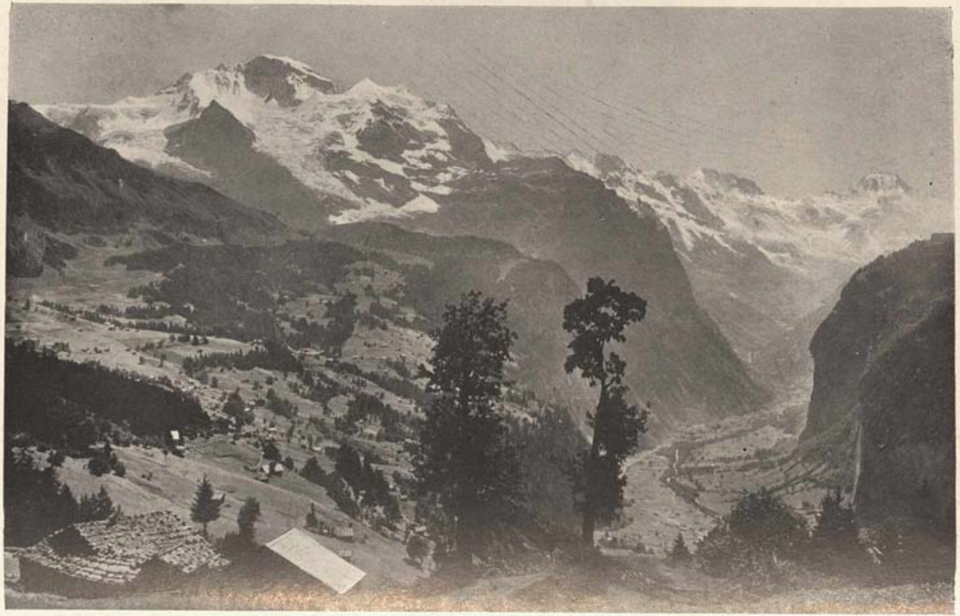
Such an unwieldy creature must have been slow of locomotion. It may have possessed the prowling habits of the bear, as well as its power of standing on hind legs when in fight. An interesting point for evolutionists is that the skeleton varied so as to adapt itself to the huge armour which it had to carry. To make the Stegosaur even heavier, all its plates and spines were in life protected by a thick horny covering, thus greatly increasing their size and weight. These formidable animals,



Pl. 66. *O* 210.

Stegosaurus.

The last word in Dinosaurian ugliness. Although American, it had English relatives (p. 210).



Pl. 67. *O* 211.

The Jungfrau, Switzerland (13,670 ft.). (p. 266).

(Photo. Wehrli, Kildeberg).

which, though "only" 20 to 25 feet long, were 12 feet high, have been found in the Rocky Mountains; and doubtful traces of them are recorded from the east coast marshes of America. They frequented Britain; one form (Omosaurus) having been found at Swindon, and another (Scelidosaurus) in the Lias Clay.

BIRD-LIKE DINOSAURS.

Turning from the heavy-weight Dinosaurs to the feather-weight types, we may comment on the Camptosaurs: herbivorous, bird-footed creatures, all bipeds, with the fore limbs much shorter than the hind ones, and having all the bones of their limbs light and hollow. These animals, with their small heads, and long, flexible necks, were graceful and agile; some of the smaller ones, in fact, were bird-like both in outward form and internal structure. Yet even these creatures attained a length up to 30 feet, and a height of 15 feet; and the smallest of them was 10 feet long and 6 feet high.

They may be considered as near allies of the well-known British Wealden Iguanodon, although they were altogether slighter and weaker than that doughty creature. Other allied forms were the Dryosaur and the Laosaur; the latter had many of the characteristics of the ostrich, although it was larger.

MARINE REPTILES.

Besides the hosts of Dinosaurs, all the Jurassic lands owned, either in rocky caves, or in putrid marshes, or in the creeks and estuaries, and even far out in the open ocean, many other reptiles; only a few of which we can spare space to mention. Crocodiles were both numerous and large; and Turtles and Tortoises were to be found in increasing variety as the age wore on. But the water-loving reptiles which most deserve our attention were the two great marine lizards, Ichthyosaurus and Plesiosaurus.

The Fish-Lizard, Ichthyosaurus.

The Ichthyosaurus (Fish-Lizard) had a fish-like body without any distinct neck; and was probably covered with a smooth or wrinkled skin (Plate 60). Its nose was elongated, and it had enormous eyes, the eyeball being protected by a ring of bony plates. Its jaws carried a formidable array of fang-like teeth. All its limbs were converted into swimming paddles; nevertheless, it was strictly air-breathing, like the whales, to which it had more than a passing resemblance. It was in the habit of diving to considerable depths; and thanks to its great eyes, possessed extraordinary powers of vision, especially at night. It lived on ganoid fish and anything else which it could manage to cram into its voracious mouth. The largest complete Ichthyosaurus, which comes from Lyme Regis, is 28 feet long by 8 feet across the paddles; but partial remains exist of very much larger ones. This lizard was a great traveller; for in addition to numerous remains in Britain, Ichthyosaurs have been found in the Arctic Regions, in Europe, India, East Africa, North America, Australia and New Zealand.

The Sea Dragons.

The Plesiosaurus, or Sea Dragon, was as long as its contemporary, but rather broader (Plates 63, 71). No fewer than fifty-eight kinds are known to science; the largest, perhaps, is Pliosaurus, which had a swimming paddle 7 feet long and a jaw 6 feet long, while one of its teeth measures 15 inches. This last, which inhabited Britain, has been found near Ely, and also in Dorset. The Plesiosaurus proper has been found, among other places, at Street, in Somerset; at Lyme Regis, Whitby, Peterborough and Weymouth; while abroad, estuarine and freshwater representatives of it have been exhumed from tombs as far apart as Griqualand and Brazil.

In regard to the habits of the Plesiosaurus,

"That it was aquatic is evident from the form of its paddles; that it was marine is almost equally so, from the remains with which it is universally associated; that it may have occasionally visited the shore, the resemblance of its extremities to those of the turtles may lead us to conjecture; its movements however must have been very awkward on land, and its long neck must have impeded its progress through the water, presenting a striking contrast to the organisation which so admirably fits the Ichthyosaurus to cut through the waves" (151).

Flying Lizards.

Lastly, we come to the Flying Lizards (Pterodactyles) and the First Bird (Archæopteryx) (Plate 68, *1*). The latter may be dismissed very briefly. It was feathered, and it was nearly as big as a rook; but it had many lizard-like affinities—in particular, the tail was longer than the body. Only two specimens are known; but in part explanation of this, it may be pointed out that birds are more liable to destruction before burial than almost any other creature possessing a bony skeleton; and throughout the geological record, their remains are exceedingly scarce. It is obvious, however, that the making of the bones of lizards pneumatic, and the alterations of a bird-like character which took place in their structure during the Jurassic, indicate that birds cannot have been much older, at any rate, than the Trias.

The Pterodactyles were the last and most nauseous of the nightmares of this world of bad dreams (Plate 59). They had a very long, bony head, jaws generally armed with teeth, and a kind of beak. The outermost of the fingers was enormously elongated, in order to support a membrane by means of which the creature flew—presumably in the same way as bats. Its eyes being exceptionally large, too, it probably went on its expeditions by night, and lay hidden in the long grass or on the trees by day, a nasty and disgusting thing. It spent at least a part of its life on the ground, however, for it could stand erect. An English form from the Lias of Lyme Regis had a skull 8 inches long, and a wing spread of 4 feet; but very much larger Pterodactyles have been described from abroad. In the next age, an allied creature existed which measured 28 feet across the wings; a nocturnal prowler at which almost any heart might quail.

CHAPTER IX.

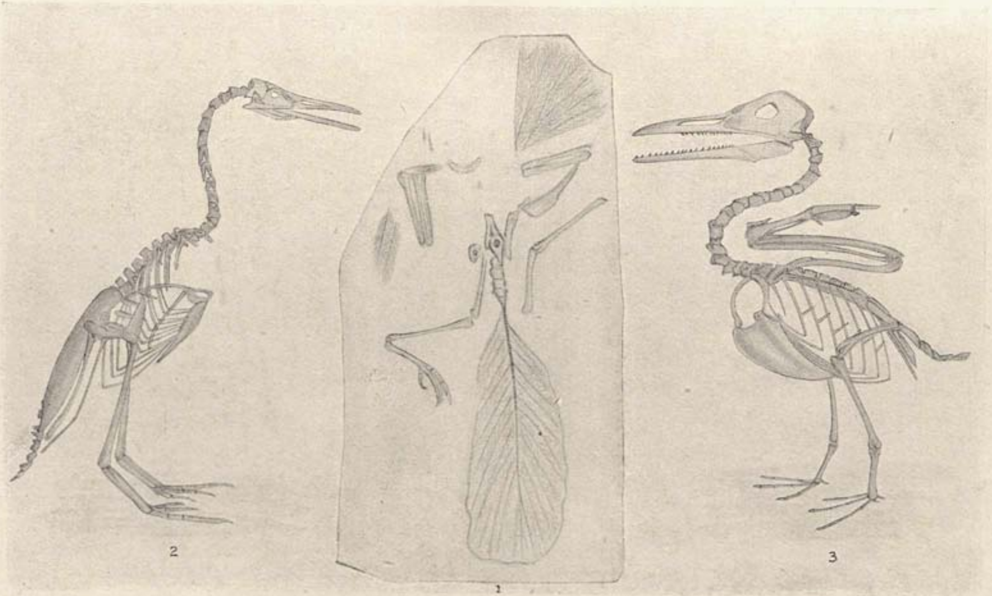
The Age of Chalk (*Cretaceous*).

ONE of the greatest difficulties with which the science of geology has to contend is the general topsyturvydom which is written in all its records. Take, for instance, the case of the Chalk. An observer standing, let us say, upon the top of one of those downs which run in a long line parallel to the south coast of England, might feel much as a sentry upon the ramparts, so steep are the slopes which separate him from the lower grounds, were it not that the soft haze which closes in the distant prospect, and the pleasing cornfields and drowsy villages which dot the nearer view, dispel all thoughts of matters military. Regarding the placid sheep as they browse upon the short and slippery grass, and filled with the restful silence which is the chief delight of lonely places, it is hard for him to imagine that the chalk down has ever been anything but a chalk down. Yet let him but poke a hole through the thin coat of soil; and, taking therefrom a handful of loose chalk, let him shake it up in a glass of water, pour away the limy liquid, and examine the residue under a fairly high-power microscope; and he will find that he is not on a hill at all, but on the bottom of an old ocean bed! For he will be unlucky indeed if, among the matter on his slide, there is not a fair number of tiny shells of exceeding delicacy and beautiful design. These shells are the cases of foraminifera, minute oceanic animals (Plate 85). Originally floating at or near the surface of the sea, they have sunk when dead to the bottom, and there accumulated to form this chalk. Wherever he searches in the chalk—be it at the crest of the hill, or down in the bottom of the combe—he will find these shells. The chalk, in fact, is composed almost entirely of them and of their fragments. And as such deposits are at present only formed in the deeper waters of the ocean—to wit, the present Atlantic, down to about 12,000 feet—and there is no great reason why they should have formed any differently in the past, it becomes plain that the existing hill was once a sub-marine abyss. It is only by remembering little facts like these, that we really begin to understand the meaning of the word "eternity."

The age in which the Chalk accumulated was the successor of the Jurassic. In some aspects, it was a sort of transition period between the Middle Ages and the Early Modern Age of the Earth's history. Too far removed from the present to be called its dawn, it yet possessed within itself most of the germs that subsequently blossomed into our abundant and varied flora and fauna. The geography of the times was, however, essentially different, as a rapid glance will show us; rapid it will have to be, for the accumulation of data regarding the more recent ages of our story is so vast that we can only take out a fact here or there, leaving the reader whose curiosity is sufficiently aroused to search in larger tomes for all but the major facts.

Development of the Chalk Age: the Wealden.

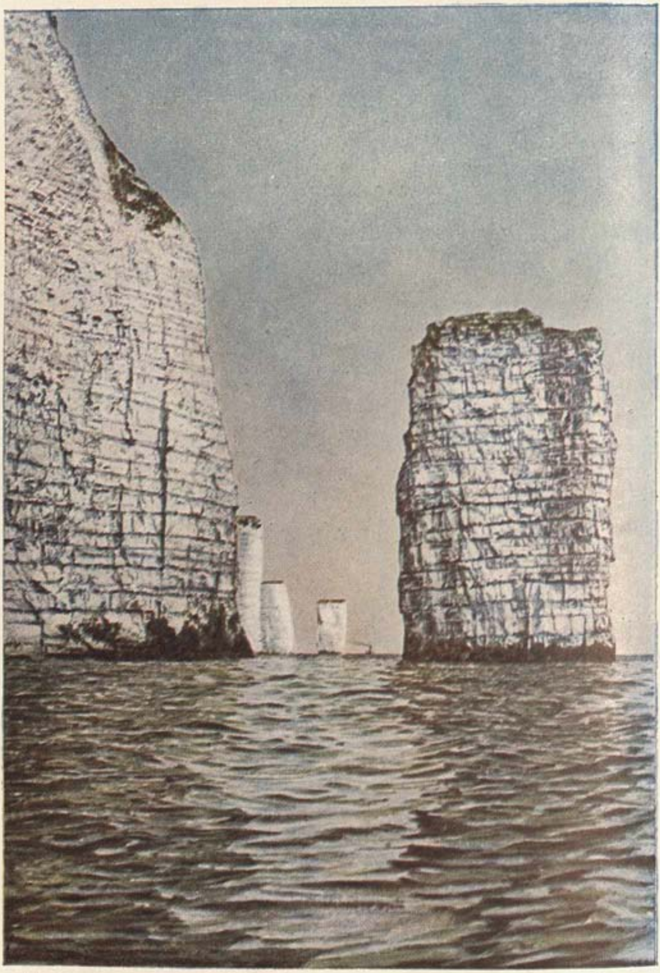
To begin with a paradox: although called Cretaceous after the Chalk, the latter is only an *incident* in that vast period of time. We left the Jurassic seas gradually withdrawing from our shores. All the way from Devonshire to Hainaut and Flanders—across the Isle of Wight and the English Channel—the land emerged: not rapidly, as on certain prior occasions,



Pl. 68. *P* 216.

The Oldest Birds (pp. 213, 234).

1. Archæopteryx. 2. Hesperornis. 3. Ichthyornis (2, 3, after Marsh).



Pl. 69. *P* 217.

Chalk Stacks near Swanage. (p. 221).

but very gradually and haltingly, as if loth to leave the cold embrace of the sea. It formed a vast plain that was raised but little above tide. In some places, such as the Isle of Portland and Purbeck, repeated alternations of marine and freshwater conditions took place, lagoon, marsh and shallow sea succeeding one another with monotonous repetition; but in the end the land won. There were granite mountains in Devon, and ordinary mountains in Wales. In the north, the land rose to greater heights than at present; and the Highlands of Scotland, in particular, formed an imposing knot of peaks.

The climate was probably everywhere very warm and humid; and much of the lower country was certainly a tangle of pine woods and marshy, fern-covered areas, with numerous clumps of beautiful palms and palmettos. In the higher, drier parts, sequoias or bigwood trees reared their stately heads far above the struggling plants below. A great river, or possibly rivers, flowed to the south, emptying somewhere into the central part of the English Channel; and the flat plains which bordered the sea formed part of its large and complicated delta. It must have been subject to heavy floods; and, flowing as it did through soft rocks, it may have often altered its course, in the inconsequential manner common to large streams. In this way, it built up the ground in the neighbourhood of its delta to a total thickness of over 1,000 feet; so that for many, many centuries there must have been a slow subsidence keeping pace with the accumulations. These delta deposits, the treacherous and sticky surface of which is the abomination of every cyclist or pedestrian, form the Weald Clay. The extreme length of the period during which they were being formed is shown by the fact that during the same time numerous coal seams were created in and near Hanover. There, the flat shores must have been subject to inundation periodically from the sea; or possibly lagoons existed, which got choked with vegetation, silted up, and submerged, time and time again; for at

Diester there are fifteen coal seams varying up to a yard or so in thickness, and these are all of about the same age as the Weald Clay.

Some Aspects of the Weald.

What transpired in the higher lands during all this time is not known; geology is always silent about what goes on in the uplands, for the remains that form the basis for such a narrative as mine are rarely preserved, except in deposits of plains or estuaries. But the hills were probably lonely and desolate, except for vegetation; the animals which love such haunts in these days had not yet been evolved. Torn by tempest and lightning, gnawed at furiously by rain and torrent, the hills have ever in the past seemed to have no purpose beyond dumping matter down into the plains. As for the latter, they were very much alive in Wealden times. The virtual lord of creation there was a gigantic reptile (Iguanodon), 15 to 20 feet high, the formidable skeleton of which is—strange anomaly! —now a terror to small boys in the Natural History Museum (Plate 73). There were a few Dinosaurs, survivors from the Jurassic. Crocodiles and turtles basked in every muddy creek. Among the fringes of reeds flew a dragon-fly of extraordinary dimensions—it was 28 inches across; and there were doubtless also hosts of smaller insects, and a number of birds: of the latter, however, no trace has come down to us, bird remains only being preserved under very exceptional circumstances. Both out at sea and over the land, flying reptiles of bizarre appearance made hideous the otherwise attractive scene. In times of flood, the rivers in their furious rush carried away numbers of dead and dying trees, which formed jams, analogous to those that occur to-day in the backwaters of the Mississippi. When they reached an awkward bend, these tangles of prostrate trunks became immovable, and were rapidly buried by the rising silt. Thus, they have come down to us intact, just as the river left them. Such an one is to be found on the shore of the Isle of Wight, south of Freshwater.

Great Extension of the Mediterranean.

At this time, most of Southern France was beneath the waters of the Mediterranean Sea; and beds of limestone were laid down in what are now the picturesque valleys of the Saône and the Upper Loire. The Mediterranean still possessed the swollen boundaries that it had in the Jurassic. On the north, it extended some way into Spain; and it may have covered the site of the Pyrenees, for its deposits are found on both sides of that chain, thus indicating a through connection with the Atlantic. Spain and Portugal were, on this assumption, a great rectangular island mass, higher on the east than the west; and fringed along the shores of the Atlantic by a luxuriant forest region, many of the plants of which have been preserved in Portugal. Italy, together with most of the Alps and the Tyrol, had at this time no existence. All was open sea as far west as the Carpathians. Here, as in Portugal, was a well-forested land, with many bigwood trees, palmettos, ferns and kindred plants. On its southern side, the Mediterranean extended even farther beyond its present limits. Besides covering an immense area in the Sahara and the Sudan, it probably extended over the site of Lake Chad, only coming to a halt against the granite hills of Nigeria. The occasional banks of fossil oysters, and the remains of sea urchins, which are from time to time found by travellers in these inhospitable deserts, form a striking testimony to the difference of that region in ages long gone past (152). On the south-east, this great extension of the Mediterranean ended somewhere on the Libyan border of Egypt and Nubia, in shallow, current-swept waters, doubtfully marine, the deposits of which form the Nubian Sandstone; in this rock fragments of fossil wood have been found, indicating that it must have been laid down near land.

Disappearance of the Wealden.

Very quietly and gradually the forests and plains, the tall trees and hideous reptiles of the Wealden passed away. The slow sinking of the whole area caused deeper and deeper water to appear in the creeks and river channels, converting dry land into morass, islands into islets, islets into shoals. Bit by bit the shoreline retreated until it was north and west of the Thames, and the site of London became once more a sea-bed. After a while, peculiar greenish sands began to be deposited in a fairly clear sea; their mode of origin has long been a matter of acute controversy, but very many, if not most of the grains are internal casts of foraminifera; the shells which once encased them having been dissolved away. In this sea, all kinds of marine organisms flourished in abundance. For instance, the remains of a great number of sponges have been found at Faringdon, in Berkshire. In the shallower waters, particularly those which covered the Isle of Wight, very large oysters flourished; the thickly clustered shells now form prominent lines in the imposing cliffs of its southern shore.

The Great Chalk Ocean.

The marine conditions did not last. There was an elevation into land, and a good deal of denudation occurred before the whole area, from Kent to Devon and from North-East Yorkshire to the Isle of Wight, once more went underneath the sea; the coast probably running from the Exe Valley in a north-east direction right across the country. This time there was no mistake about the submergence. As one went east from the shore, the water deepened rapidly, with the result that two very different kinds of matter were laid down simultaneously—

greensands in the west, and clay in the east. Eventually, the water everywhere grew deeper and clearer, until a fine chalky ooze took the place of sand and clay alike; and this continuing, the Age of Chalk set in. Eventually, all the country, as far west at least as Sidmouth, became submerged to an unknown depth, possibly in places several thousand feet (Plate 69). Northwards the waters stretched, burying deep the site of Belfast, and lapping both sides of the Scottish Highlands, even if they did not submerge them. Over in Scandinavia, areas were drowned at this time which had been land since a very ancient period. The sullen greenish-grey of the North Sea was changed to the blue-black of very deep water; the dykes of Holland, the bloodstained fields of Belgium, the great industrial centres of the Rhine—all these sites were part of the same ocean (Plate 70, A, C). To the eastward, Denmark, Pomerania, Poland and Galicia, were all involved; the sea thence stretching across Southern Russia to the Crimea into the Caucasus; and in all this space, practically the only islands were in Bohemia, in Saxony, and in the Carpathians. To an eye weary with constant voyaging among uncharted seas, the magnolias, aralias, fig trees and ivy, which, among other things, inhabited the few islands, come as a welcome relief. On the south of Britain, France was involved, of course; in fact, the France of the Feudal Ages was quite a large territory compared with that of Cretaceous times. With Paris the centre of a deep basin, and with the waters submerging successively more and more of Western France; with the Dauphiné, the Jura and the Alps, as a common meeting ground of the waters, it was a wonder that anything was left of France at all (Plate 70, C).

Countless Animals that are buried in the Chalk.

This state of things endured for a vast interval of time; and during all that time, practically the only matter which accumulated in any bulk on the bottom was the dead bodies, in their beautifully-fashioned cases, of Foraminifera. Now, there is no reason to think that at any particular moment these tiny organisms, up to 6,000 of which have been found in an ounce of sand, were very much more common in the open ocean than they are at present; and the constant rain of their dead bodies upon the ocean's bottom cannot have amounted to much in a year, or even in a century. In proof of this, we may remark that it is not uncommon to find sea urchins (Plate 72), the skeletons of which had been taken possession of by delicate "lace corals"; and the latter having perished in turn, their surface formed a home for numerous serpulæ; all this transpiring before sufficient mud accumulated to bury one small sea urchin! When it is recalled that the Chalk has a maximum thickness of more than 1,200 feet, of which the great bulk is skeletons of Foraminifera, our reference to "a vast time" becomes more than a platitude.

Besides the organisms we have named, a moderate variety of shells, various corals, and sponges, and some curious crinoids, inhabited the deeper parts of this ocean; up above, there were undoubtedly many kinds of fish, but the number that was preserved fossil is limited. As to the Foraminifera, the most common kind, perhaps, was Globigerina (Plate 85, *2*), which is apparently identical with the form that is now most common in the deposits of the deeper waters of the Atlantic.

The sea urchins have proved invaluable as a means of subdividing the Chalk into zones; different species occurring at the various levels.

Africa in this Age.

Turning from Europe, we must not forget that the rest of the world was not standing still during all this time. North Africa was part of the Chalk Sea. The south-central mass of the "mysterious continent" still remained, as it had done for countless ages before, a much-worn, storm-scarred block of highlands, rising far above the restless ocean. But its fringes participated more or less in the fashions of the day, and had an occasional dip in the sea. There were flat, wet, fern-tenanted plains in what was some time ago German East Africa; and hereon, in vivid mimicry of their American cousins, Dinosaurs stalked about. One great beast, a kind of Diplodocus, was—incredible circumstance!—considerably larger than anything America had to show; its neck alone being 39 feet long, while that of its American cousin was only a *mere* 23 feet (153). This animal, which was found at Tendaguru, has been named, appropriately, Gigantosaurus. In Somaliland, the early part of this age was marked by volcanic outbursts; later, the sea came in and swamped them; later still, there was land, which succeeded in enduring until the next age, when there was a recurrence of eruptions. On the other side of the continent, a large area in Yorubaland, the Oban Hills, and other parts of Nigeria, formed island masses in the sea; but as the age wore on, the waters withdrew between here and the Cameroons, marshes accumulated, and valuable beds of coal were formed (154); while in the neighbourhood a few volcanoes intermittently gave proof of their existence, and sheets of molten rock were intruded as dykes.

The Borderlands of India.

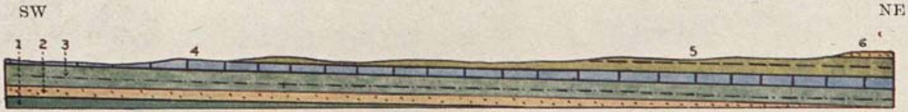
Coming to Asia, in the early part of this age, Turkestan and Afghanistan formed a great landlocked water zone, with possibly desert conditions prevailing in the surrounding country. The vast transgression of the sea which followed, however, did not spare this remote region; since it buried much of Afghanistan, Baluchistan and the adjacent parts of India; only to gradually withdraw again ere the age reached its close. The regions about the Persian Gulf, also possibly a desert, were intermittently volcanic throughout this time; much of Persia itself was a clear sea area. The great peninsula of Hindostan remained a land mass, apparently, throughout the age; and on its north-eastern frontier, the Shan States and China formed another great land. The sea at this time washed the southern flanks of the Assam Range, and was gradually filling up the deep depression that fronted the land there.

THE DECCAN TRAP.

We now come to an incident almost without parallel since the ancient Keewatin days—to wit, the creation of the Deccan Trap, which took place in the later stages of the Chalk Age. This is a great mass of rocks, mainly basalt and dolerite lava flows, almost horizontal, with beds of ash and deposits that were laid down in lakes; covering 200,000 square miles, and extending over nearly 10° of longitude and 16° of latitude, it covers the whole of the plateau of Peninsular India (Plates 18 B; 74). Prior to the outbreaks, the surface seems to have been very uneven, particularly in the west; and it was there, in what are now Bombay, Cutch and the Narbada Valley, that the principal foci of the eruptions were located. There were many separate lava flows, separated sometimes by very considerable intervals of time. Though of no great thickness—averaging perhaps 6 to 10 feet—the flows were excessively fluid, and in their hurried course they floated away considerable masses of rock and ash. In some of the pauses between the eruptions, lakes were formed on the hard and scoriaceous plains, probably through the lava streams having diverted the course of the rivers; in these lakes, frogs, small crustaceans and fish abounded, while their shores were beautified by an ample mantle of vegetation. In the marshy parts, dinosaurs wandered; on the beaches turtles crawled. Then would come another great eruption, and the obliteration of the whole.

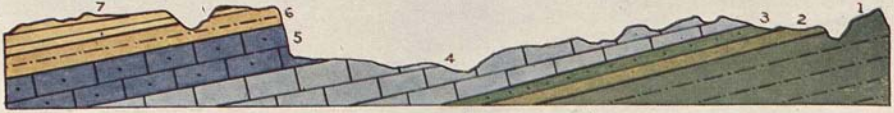
A: The London Basin (after Woodward).

1-3. Jurassic. 4-6. Greensand and Gault. 7. Chalk. 8. London Clay, etc.



B: The Great Plains, Dakota (after Darton).

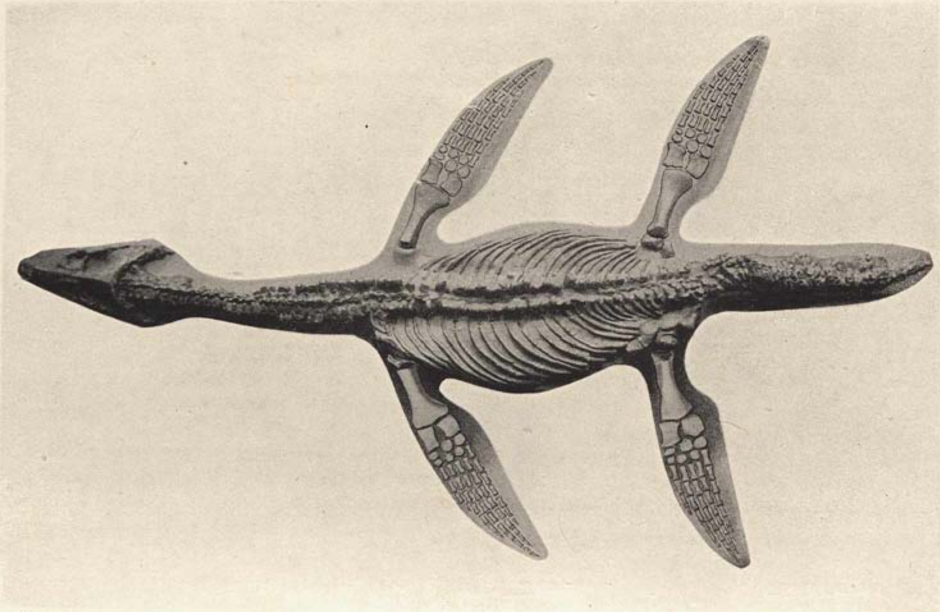
1. Lower Cretaceous. 2-6. Upper Cretaceous. 2. Dakota Sandstone. 3. Carlile Shale. 4. Niobrara Chalk. 5. Pierre Shale. 6. Fox Hills Sandstone.



C: Champagne (after Imbeaux).

1. Albian. 2. Cenomanian. 3. Turonian. 4. Senonian Chalk. 5. Danian Chalk. 6-7. Eocene.

Sections through Cretaceous Rocks.



Pl. 71.

P 225.

Rhamaleosaurus.

A British ally of the Sea Dragons (p. 212), but considerably larger.

This went on until a maximum thickness of considerably over 6,000 feet of matter had accumulated; indeed, it only terminated with the age itself. This outpouring of molten matter has only three incidents with which it can be compared, either for size or duration, in the Earth's history: the Keewatin and Brazilian outbreaks, already referred to, and the Columbia lava plains, of which we will speak later.

Australia and the Far East.

In passing, it may be noted that, with the exception of Queensland, Australia still formed part of a much larger continent, the foreland of which was probably New Zealand. In the latter country, the general lines along which the great massif of the Southern Alps was to be built, had already been laid down; but the creation of the mountains as we see them to-day had yet to come: in fact, the highlands of those days were in what is now the Tasman Sea. Japan, also, was a foreshore to the Chinese lands, for most of its rocks of this age are marine.

Economic Value of Deposits in North America.

Finally, we come to America. Here, especially in North America, the Chalk Age rocks have received great attention, for the practical reason that they are the sources of numerous most valuable oil pools and reservoirs of natural gas. These rocks are also the graveyard of myriads of plants, which show a progressively greater approach to modern types as we pass from the beginning to the end of the Chalk Age.

Abundance of Animal and Plant Life there.

The general paucity of Jurassic rocks in North America indicates that most of it was land at that time. On the east, in particular, the long line of the Appalachians fronted the Atlantic just as it does now, but the plain that fringes it was then much narrower. With the coming of the Chalk Age, this plain underwent a number of striking vicissitudes. Not to weary the reader with too much detail, it suffices to say that, from Alabama to Pennsylvania, it was, first, a low, forested marshy tract; then a sea-bed; then land; then a lagoon area; then marine again; and so on, right to the end of the story. In the early or forest stages, a few Dinosaurs, survivors of the old Jurassic forms, still wandered about; among these was the gigantic Allosaurus. There were also slender bird-like forms; and crocodiles, about 6 feet long, very similar in appearance to the modern crocodile. The plant remains are very numerous. They enable us to picture up a country abounding in large-fronded ferns and palmettos, enjoying an equable and mild climate, with abundant rain (Plate 75). Although the petrified annual growth rings in the fossil wood indicate seasonal changes, they do not particularly suggest any degree of cold in the winter; and generally, except for the Dinosaurs and the insects, it must have been as fair a place to live in as we have up to now happened upon. There was a considerable variety in the early Cretaceous plant life, which included 43 species of ferns, 2 horsetails, 33 palms and palmettos, 29 different pines, and various others in the earlier parts of the age (155); while later, the angiosperms, the dominant form of vegetation to-day, were developed in abundance. It is interesting to note the first appearance of flowering plants, the earliest Poplars, as well as Ivy, Laurels, Spindle trees and several other shrubby trees. There was also a primitive form of water lily. (See Plate 75.)

The Great Interior Sea.

During the first half of the Cretaceous, the sea covered much of what is now the drainage basin of the Mississippi, extending as far west as the Wasatch Range in Utah, and from the Mexican Gulf to the Arctic Ocean. Thus, all the low plains whereon the Jurassic Dinosaurs had grazed were submerged; and these creatures were presumably driven into the more westerly States of Colorado and Nevada. Here they attained a degree of over-specialisation that strikes one as ludicrous, and to which we will refer again in a moment. The submergence gradually extended eastward across Dakota until it reached central Minnesota and Iowa. Molluscs, fish and seaweeds were abundant, and the sediments were locally heavily charged with oil from their remains. At one period, the water shallowed greatly; and over a vast area a relatively thin band of sandstone was laid down: this, which is known as the Dakota Sandstone, may be described as the salvation of the Middle West. It lies, on the whole, between great masses of shale that do not carry much water, and as the regions in which it is found are semi-arid, it is the main source of the water supply for the many enterprising farmers and ranchmen who have settled there. At another period, the sea was deep and clear enough for chalk to form—not on a scale comparable with that of the English Chalk, but yet an interesting example of natural changes, since these chalk beds are now in the heart of the continent (Plate 70, B). Towards the close of the age, all the marine waters withdrew from the Interior States and from Canada; lakes, marshes and river plains regained the ascendant; and the land began to have some faint resemblance to its modern configuration. But Mexico and the West Indies were probably, by way of compensation, almost non-existent.

Large Freshwater Lakes.

The lakes that ended the Chalk Age in America had an immense duration both in time and space. Many of them appear to have been vast meres, bordered by extensive marshes, the matted and rotting remains of which, closely compressed and buried beneath the mud brought down by the numerous streams, became beds of peat, often of great thickness. Further compression has transformed much of this into lignite or brown coal, and a considerable part, by the loss of more moisture, has even become bituminous coal of considerable heating value. There is little, if any, resemblance between the mode of origin of this coal, and that of the Coal Age proper; while the plants forming it are, of course, wholly different.

Cretaceous Coal Deposits.

How great are the reservoirs of fuel that were thus created may be gathered from a single instance. The Cretaceous coals of the Grand Mesa and West Elk Mountains in Colorado—only one field out of many—were estimated in 1912 to have a workable thickness of up to 65 feet of coal, and a quantity available of 12 thousand million tons (156). But many of these American coalfields are very largely lignite, and have at present but little commercial value, the heating power of the coal only being about one-half that of true coal; nevertheless, in the future their importance will gradually increase, as the better grades of coal become exhausted. At present, owing to the general absence of wood in the Great Plains of North America, this lignite is very precious to the settlers for local use, providing them with both fuel and power; and as beds often lie almost horizontally, just beneath the surface, they can easily be got at by merely stripping off the soil and subsoil.

It is almost unnecessary to remark that lignite is coal in the making. It is, of course, not nearly so compressed as coal, and it frequently has a woody texture, the wood sometimes being so well preserved as to retain its elasticity: thus, after being bent, it will whip back like a branch newly cut from a tree, and the fact that it has lain for thousands of centuries in the ground seems scarcely credible.

Variety of Plants (Plate 75).

The lands upon which all this Cretaceous plant-debris grew would assuredly have been an elysium for a botanist. Besides the many ferns, sedges and reeds down by the water, there were willows and alders along the river banks; higher up, extensive forests of oak, twined about with ivy, sheltered occasional walnuts and other dry-ground trees. Groves of poplars were there in plenty; as well as tulip trees, laurels, magnolias, cinnamon trees and grape vines. Fan palms, great in number but meagre in variety, and occasional bread-fruit trees were constant denizens of this green wilderness. Cypress swamps were also numerous; and hereabouts grew a large variety of fig trees. The highlands were clad with eucalyptus trees, the moors with early forms of heaths and euphorbias; and on the mountain slopes, rising in stately isolation from amid the clumps of pines, rose the Bigwood Tree, Sequoia, the lord of the vegetable world (157). Flowers, however, the gorgeous carpet of Mother Earth, were probably rare; but a very few specimens have been found in the deposits of the succeeding age, the Eocene.

Canada.

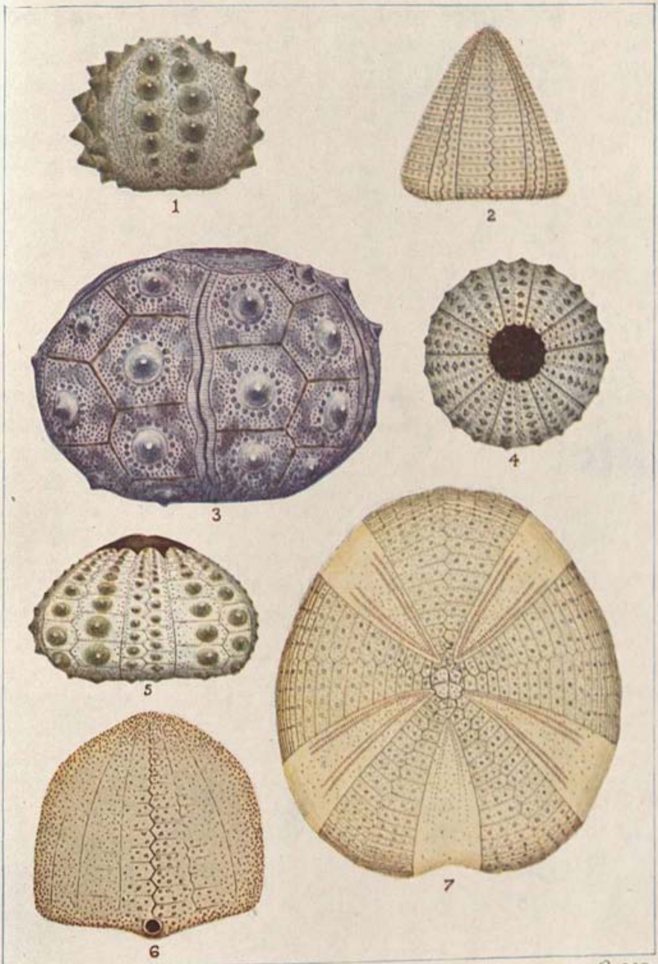
In the corresponding part of Canada, similar conditions prevailed. It will be remembered that in the previous age (the Jurassic) the injection of immense masses of granite had created the Coast Range of B.C. These were bordered on their eastern side by lowlands that formed a most suitable home for the abundant flora of Cretaceous times. The results are best expressed when turned into coal. In the Crowsnest Region, B.C., there are twenty-two seams of such coal, having a total thickness of 216 feet, and an estimated quantity of 23 thousand million tons (158). As all this great quantity had to live and perish, largely in the form of narrow reeds, twigs and thin leaves and moss, the immensity of the time during which it was "in the making" becomes apparent. Beside such facts, the Egyptian records are but a thing of yesterday. At Corbin, B.C., one of the seams varies in thickness from 10 to 250 feet—the latter extraordinary thickness may be due to the rocks having been folded back upon themselves, but even then it is enormous (159).

Rapid Destruction of the Land.

Such a forest required much moisture, and got it. But this same drenching rain was rapidly eating away the tops of the newly-created mountains, and cutting a path to the deeply-buried granite masses which are to-day the major part of those heights. Most of the drainage seems to have been to the west, where there was created, doubtless as a result of the injection of the granite masses, a zone of weakness that ran generally north-and-south. Into this depression, which was covered by the Pacific, was poured all the matter stripped from the mountains; to such effect that a thickness of 30,000 feet of shales and sandstones was there deposited. The existence of this extraordinary mass of sediments is proof positive that the great oscillations of the Earth's crust that took place in the earlier ages of the geological story were no mere local phenomena, but part of a process which has furnished examples even later than the Chalk Age, and may be going on, almost or quite unsuspected, in some part of the world to-day.

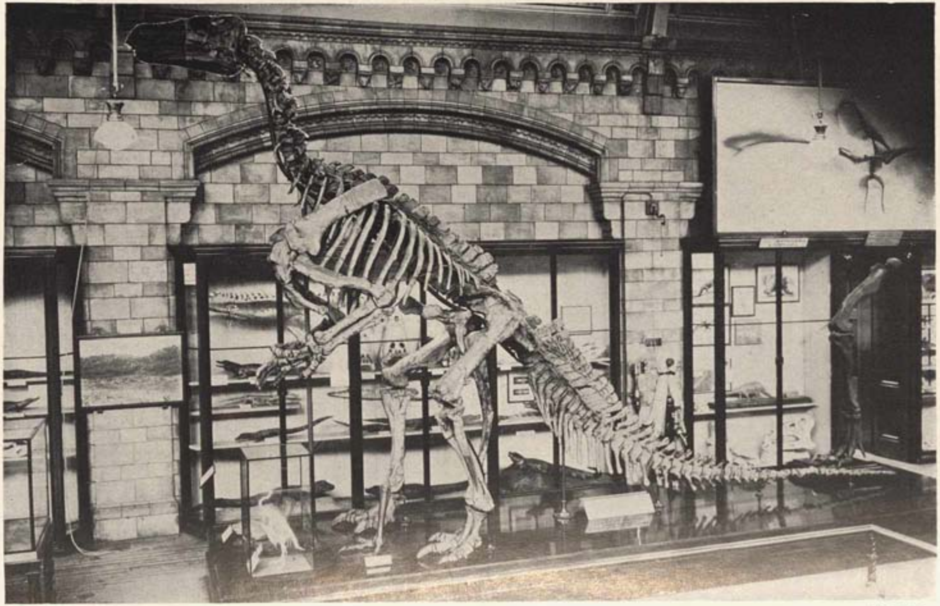
Great Resources of Petroleum.

Another of the many treasures which Nature put into her North American storehouse during the Chalk Age was petroleum.



Pl. 72. Q 230.

Cretaceous Sea Urchins (p. 222). 1 Hemicidaris. 2. Echinoconus. 3. Cidaris. 4. Pseudodiadema. 5. Goniopygus. 6. Echinocorys. 7. Holaster.



Pl. 73.

Q 231.

Iguanodon.

A familiar figure in Southern England when the Weald Clay was being deposited. This skeleton is 25 feet long.
(pp. 218, 233).

Many thousands of wells have been sunk into the Cretaceous rocks of the Great Plains and the Middle West, and an exceedingly great quantity of oil extracted therefrom. It is believed that the large coarse seaweeds which abounded when marine waters covered that area are largely responsible for this richness in petroleum. The total quantity recovered cannot be computed without an unreasonable amount of research, since part of the oil from these areas comes from Coal Age rocks; but it certainly amounts to many millions of barrels, each of 42 Imperial gallons. In quality, the oil varies from a light kerosene to a heavy asphaltic mass scarcely able to flow.

Natural Gas.

With the oil, and in some localities where oil has not been recovered, occurs a great quantity of natural gas. This has been used for illuminating purposes, and for heating and power; but owing to wasteful methods, much of it has been lost. The life of a natural gas reservoir is a short one. The gas was originally stored in porous rocks, such as sandstones; and where oil and water are also present, the oil is found below the gas, and the water below the oil. Once the gas has been tapped, the very greatest care is necessary to avoid its waste and dissipation into space. Some of the reservoirs originally attained very considerable dimensions. For instance, in the Petrolia Oil Field, in Texas, there was originally, in 1907, about 110 thousand million cubic feet available, of which only one-tenth remained in 1920 (160).

Greenland in the Chalk Age.

Continuing our survey, we will go north to Greenland. In the early part of the Chalk Age, a large part of the west coast of this frozen land was below sea-level. Later, the land emerged, only to be buried beneath a volcanic deluge, and then, after a considerable interval, by another. Between the two, there was a time when land plants took possession of the place, growing upon the soil formed from the crumbling surface of the earlier lava flows. In the lakes and marshes, plants essentially similar to those found in the central United States flourished abundantly. The climate was warm temperate to sub-tropical; the northern latitude and the restricted amount of sunlight apparently having no effect on the growth of the plants. We shall have something more to say about this phenomenon in a later chapter.

South America.

Jumping, with an author's licence, to South America, we find that continent very different from what it is at present. The great basin of the Orinoco was below sea-level, and the sandstone precipices of Mt. Roraima were then in the making. Brazil was apparently land, but the Amazon had no existence. The site of Lake Titicaca was also beneath the ocean; for a Cretaceous sea urchin has been found at Peñas, now some 12,000 feet above tide (161), and rocks of the period are built into the Western Andes (Plate 79). Land may have stretched from the widest part of the continent eastwards to Africa, and so permitted a commingling of the life forms; but there is no strictly geological evidence of it. Farther south, plant remains, accumulated in river flood-plains and in lakes, litter the Argentine as far down as Tierro del Fuego. Some of the drainage seems to have gone to this austral region, and to have been of the same character as that on the Red and Arkansas Rivers; many uprooted trees having been carried down and formed into huge jams, by the side of which that found in the Isle of Wight is a midget. The petrified trunks have been observed in masses piled up to a height of 20 to 30 feet (162); all, of course, buried in altered mud. Where the forest opened out, Dinosaurs of formidable dimensions roamed; and, in general, the world here was much the same as in the middle United States or in the far north. Indeed, the uniformity of conditions of climate and life in the Cretaceous lands is very striking; even in Antarctica, Bigwood Trees occurred.

In the course of our short tour round the globe, we have already referred to many types of the life of this age; but some of them call for a little more particularisation.

Over-specialisation of the Dinosaurs.

The Dinosaurs had passed their prime. The nice adjustment of size to circumstances had long since gone by; they present us now with specimens as unwieldy as they are hideous. Covered with all sorts of defensive armour, they were becoming mere Goliaths that any agile David might slay. In number, apparently, they did not diminish; but they compensated for this by perishing, *en bloc*, with the age itself. They were extraordinarily abundant in Alberta, whence a valuable series has been disinterred. (*See* Plates 76, 77, 78, 81, 82.)

Iguanodon.

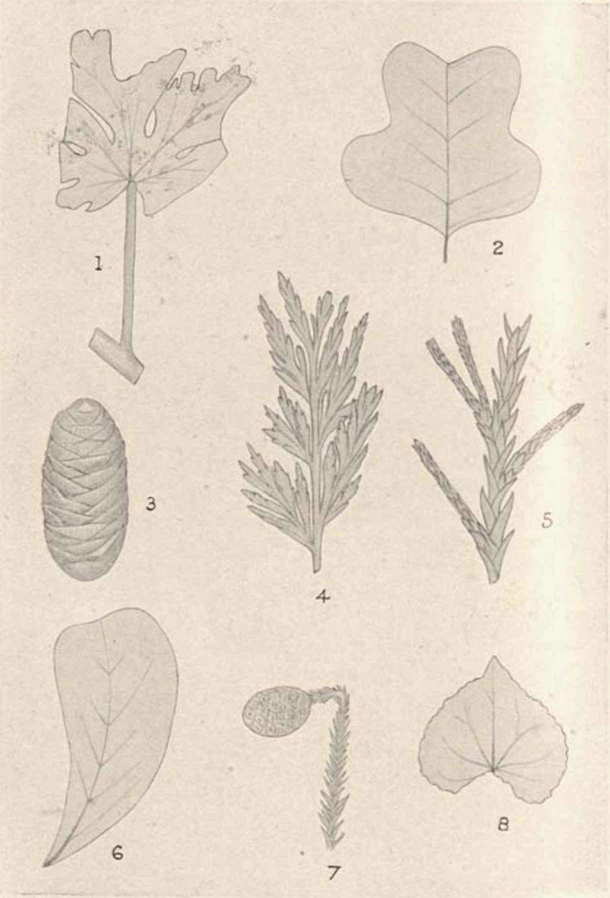
The gigantic Iguanodon, which frequented the woods of the Wealden, and which was 50 to 60 feet long, standing moreover upon two legs only, was yet a plant-eater, and probably nothing but a browsing nightmare (Plate 73). The flying lizards, or Pterodactyles, with their sword-like noses and strong powers of flight, were more formidable; not the less so, because some of them were 20 to 25 feet across the wings (Plate 59). Their bones were far lighter than those of birds; a bone 26 inches long and 2 inches diameter was no thicker than a sheet of blotting paper! Some of the slender, kangaroo-like Dinosaurs must also have made awkward enemies. But the huge, armour-plated creatures, of rhinoceros-like form, which wallowed in the muddy marshes, need excite no fear in any one; even their charge was doubtless a slow and cumbrous manœuvre. Some of them fought often—possibly each other; for the broken stumps of their horns have been found more than once. The two best-known types are Triceratops and Ceratops. In the former, the skull exceeded in size that of any known land animal hitherto described (Plate 80). Skulls of comparatively young ones were 6 feet in length; and the full-grown beast must have had a head some 8 feet long. This formed a great bony shield round a ridiculously tiny brain, no larger than a man's fist. The shield was armed with a sharp cutting beak, a very strong horn on the nose, and two large pointed horns on the top of the head, as well as a row of sharp projections round the margin of the skull. The teeth formed a single cutting row in each jaw, and acted like a pair of shears. Triceratops stood some 10 feet high, and was about 25 feet long. Its weight must have been tremendous, all its bones being solid. From the uppermost American Cretaceous rocks, no fewer than five hundred fragmentary skulls, besides innumerable bones, of Triceratops have been unearthed.

Cretaceous Birds.

The birds of the Chalk Age were still very reptilian in appearance and habits (Plate 68, *2*, *3*). The most curious of them, perhaps, were the toothed birds whose remains have been found in the lake deposits of the United States. These, which had a general resemblance to the ostrich, except that they were water-loving, had very rudimentary wings; progressing by the aid of their powerful hind legs and flat broad tail through the shallow marshes that they inhabited. One of the best-known of these birds was Hesperornis. "It must have been an admirable diver. Its long flexible neck and powerful toothed jaws would enable it to catch the most agile fish, while as the lower jaws were united in front only by cartilage, as in

Pl. 74. Q 234.

Near Kandala, W. Ghauts, India (p. 224).
In the region of the Deccan Trap.



Pl. 75. *Q* 235.

Cretaceous Plant Types. 1. Cissites. 2. Liriodendron. 3. Cedrus. 4. Onychiopsis. 5. Widdringtonites. 6. Myrica. 7. Sequoia. 8. Populus (pp. 226, 229).

serpents, and had on each side a joint that admitted of some motion, it had the power of swallowing almost any size of prey" (163).

SEA SERPENTS.

The most curious animals of this age were the sea serpents. There are no living sea serpents, except a few in the Indian Ocean; but they were at that time a very terrible reality. They abounded in the interior seas of North America, and were not uncommon in Europe, even in what is now the mouth of the Thames. Over forty different kinds, varying in length up to 75 feet, are known. They were eel-like creatures, with large flat heads, and eyes that were sometimes directed partly upwards. Their swimming apparatus comprised two pairs of paddles like the flippers of a whale, aided by the powerful motions of the tail. Like snakes, they had four rows of formidable teeth on the roof of the mouth; like snakes, also, their mouth was so articulated that they could swallow large prey whole. Of such a nature was the lizard called Elasmosaur, which was some 40 feet long, with a slim arrow-shaped head and a snake-like neck rising 20 feet out of the water. "It probably often swam many feet below the surface, raising the head to the distant air for a breath, then withdrawing it, and exploring the depths 40 feet below without altering the position of its body. It must have wandered far from land; and that many kinds of fishes formed its food is shown by the teeth and scales found in the position of its stomach."

GIGANTIC TURTLES.

This was, in very truth, the age of the gigantic. Even the turtles outgrew their importance, waddling about like living warships. One specimen has been found that was 15 feet across between the tips of the flippers!

CHAPTER X.

The Age of Coin Fossils and the Age of Lakes.
(*Eocene and Oligocene*).

"DAWN OF THE RECENT."

WE have now advanced so far upon the highway of our task, that a direct although obscure connection with the present day becomes apparent. Hence the age that succeeded the Chalk bears the picturesque name of *Eocene*, meaning "Dawn of the Recent."

THE DIVISION OF THE AGES.

It is appropriate to explain here that in the early days of the science, before the succession of ages was properly comprehended, rocks were divided into three great groups—Primary, comprising everything older than the Trias; Secondary, from the Trias to the end of the Chalk Age; and Tertiary, or younger than the Chalk. Subsequently another, Quaternary, was added, to cover the recent accumulations of the surface and the Ice Age which preceded them.

The present chapter, and the next, will be devoted to the Tertiary Period as thus restricted. This was a vast division of time, certainly several millions of years; and was noteworthy for two outstanding events, one being the emergence of the continents into their present outlines, and the other the growth of the many kinds of mammals which people those lands, as well as a host of others which have since become extinct.

The Tertiary Period, again, can be conveniently subdivided into four Ages. Originally, this was done on the basis of the number of molluscs of living species which were found in the older rocks; but subsequently, this plan was modified to include certain marked physical events as well. The four divisions bear names derived from the Greek—to wit, *Eocene*, or Dawn of the Recent; *Oligocene*, or Fewer Recent; *Miocene*, or Less Recent; and *Pliocene*, or More Recent. In the first of these, the great oceans that had characterised the Chalk Age withdrew from much of the Earth's surface; in the second, further withdrawals caused the formation of numerous great saline, brackish and freshwater lakes; in the third, the mass of mountains which runs almost continuously from the Bay of Biscay to the plains of Assam had its growth, and volcanic disturbances were numerous and violent; and in the fourth, the finishing touches were put to the modern topography. We will deal at present only with the first two, the Eocene and the Oligocene.

Striking Difference from the Chalk Age.

The chalk downs of our country are the record of a clear, deep sea, tenanted by shellfish, animalcules and sea urchins; but the rocks which immediately succeed them were formed along low coasts and in shallow estuaries; they lie, moreover, on beds of chalk of which half the thickness had been worn away ere ever a grain of Eocene mud was deposited. This great break represents an incalculable period of time, during which the whole of North-Western Europe was raised into land and partially worn away again; river systems created and broadened; and a continent built up, which in climate and vegetation bore more than a casual resemblance to modern

India. The southern border of this continent curved around the English Channel, skirting the environs of Paris; to the north and north-west of the Channel was land, while much of France formed a large peninsula jutting out into the Atlantic. After long ages had made the river systems stable, great estuarine deposits began to be laid down in areas centring on London, on Belgium, on Paris and on the Isle of Wight, and probably, in part, united over the whole tract embraced by these localities.

THE SITE OF LONDON IN EOCENE TIMES.

Of these river basins, that which is the most interesting to English readers is naturally the one that debouched upon the site of London. The world's metropolis, though at that time usually a short distance out at sea, was the dumping ground for vast quantities of sand, gravel and mud, which now form the upper part of the hills by which the great city is surrounded (Plate 70, A).

At first, the estuary of the primeval Thames, as we may not irrelevantly call it, ended above London—possibly in the neighbourhood of Windsor or Staines; for deposits which at Woolwich bear marine remains, become indicative of fresher and fresher water, as one travels to the west, until at Reading they are wholly riverine. As time wore on, the mouth of the river deepened appreciably and the shoreline receded still farther west, until much of Hampshire, Berkshire, Surrey and Middlesex became the site of its delta. The mountains of Wales and Devon, then very much higher than now, were not improbably the reservoirs whence came much of the mud that was now laid down in the river's mouth. This mud, accumulating for ages, formed the London Clay. The turbid streams that deposited it passed through a land totally unlike anything that exists in England to-day. Except for the chalk

Pl. 76. *Q* 238.

Unearthing a Dinosaur in Canada (p. 233).

Pl. 77. *Q* 239.

Skull of a Canadian Dinosaur.

Edmontosaurus, a Cretaceous reptile, 30 to 40 feet long, which lived on soft vegetation (p. 233).

hills, which were slowly rising all the time, the lower part of the river was apparently flat; and was clad with screw pines, palms and other tropical, damp-loving plants. The whole presented an aspect not unlike the lowlands of New Guinea to-day—a dense jungle, almost impassable, except to the creeping and wriggling things that were its native denizens. Of these, there was no lack of variety. In the creeks and on the mud flats, numbers of alligators and crocodiles basked; on the beaches, turtles and tortoises slumbered. Out in the open water, sea snakes, sometimes of formidable dimensions, preyed on the smaller inhabitants of the deep. Overhead, resting we know not where, flew a huge bird, an ally of the modern albatross; whilst in the marshes the ibis, the flamingo, the heron and the hornbill had their haunts, and on the drier ground, hawks, ospreys and buzzards preyed on smaller birds whose remains have not come down to us.

But this condition of things, though long enduring, was not immutable. The sea bottom was slowly raised into the air, and the climate, at least along the coastal strip, grew drier. The great river flowed no longer to the east, even if it flowed at all. The reptiles, the insects and the birds dwindled in numbers or fled elsewhere. A strange drought came upon this part of the land, and desert conditions prevailed for a time. Accumulations of sand, possibly windborne, were formed both in the London and the Hampshire basins; a patch of these yellow sands, the Bagshot Sand, forms the summit of Hampstead Heath, the highest part of North London. But the desert conditions seem to have been both transient and local; for shortly afterwards, we find that in Dorset fluviatile or estuarine rocks were being laid down, in which were preserved the remains of many drifted plants—Bigwood trees, Eucalyptus, Araucarian Pines and the like: all indicative of a high and well-watered land in the near vicinity. In the lower lands which bordered the streams and the ocean, Screw Pines, Laurels, Cinnamon, Vines and Figs abounded; and in the quieter reaches of the rivers water lilies swayed idly at the whim of the current (Plate 90).

Elevation of Southern Britain.

Again the scene changed; in fact, all this part of England was throughout this age in a state of very unstable equilibrium. Estuary succeeded sea bottom, and river flat estuary, with bewildering frequency. Lakes, marshes and lagoons came and went time and again. At one period most of the Isle of Wight was open water, with sea serpents 20 feet or more long in possession; at another, the same area was a mere or a marshy river flat, wherein dwelt delicate freshwater snails, and the rotting vegetation of which formed beds of peat, now converted into lignite or brown coal (Plate 88, A). Eventually, however, the general elevation of much of North Western Europe terminated all these changes. The sea bed became high and dry land, and has remained nearly the same ever since.

Long Period of Denudation.

Ages passed, during which the most stupendous changes took place elsewhere, but of which our own southern counties bear no witness. They were a region of hills and dales, slowly being worn into the familiar forms which we see to-day. So great was the constant denudation during all this time, that certain Eocene river beds can be traced, by their gravels, along the tops of the Sussex and Hampshire hills; and this is all that remains, either of the ancient streams or their valley walls. The climate almost certainly continued to be tropical; but the best evidences of it—animal and plant remains—are practically absent. This great gap in our story occupies much of Oligocene and the whole of Miocene time. We can fill it in by observing what took place in other parts of the world, where deposits were being laid down and remains buried, in such abundance that they furnish a far more complete picture of the world than any former age can show. The most striking thing about the fossil remains of the times is the great growth of mammals, of which man himself is the latest descendant.

Development of Mammals.

Taking the reader back a few chapters, it will be remembered that the earliest mammals appeared as long ago as the Trias Age, and that throughout all the innumerable changes of its successors, the Jurassic and the Chalk Ages, these early mammals remained apparently incapable of further development. Minute rat-like and opossum-like creatures they were, and as such they remained, despite the fact that the conditions on the land favoured the development of huge dinosaurs and other reptiles, all of the most complicated structure. So far as one can judge, the conditions of the Eocene Age were not markedly dissimilar from those of its predecessors. There was an equally warm, humid climate, and an equal luxuriance of vegetation. Probably, however, the growth of grasses, which now became very prominent, may have influenced the development of the ruminant mammals; but be that as it may, one thing is certain. By a touch of the wand of the great Arbiter of all things, the mammals began to grow, and not only to grow, but also to alter. In one quarter of the Earth the first primitive horse appeared—a tiny creature with five toes. In another, the earliest hoofed animals are found. Elsewhere, again, we find hornless deer and antelopes. Finally, came carnivorous animals resembling wolves, foxes and cats—all before the close of the Oligocene. The horse developed into a creature with four toes, and then one with three, at the same time increasing in size until it had the dimensions of a small pony. Ancestors of the rhinoceros and hippopotamus wallowed in the marshy regions; and the elephant roamed over the drier grounds. Birds flew over the trees in great and ever-growing variety. In the sea, the earliest whales appeared (Plate 87). It is all very wonderful and strange—a gigantic step towards modern times, following upon a long period of inertia. The mammalian germ cells responded to the call as readily as those of the Jurassic reptiles had done: *why*, is a complete mystery.

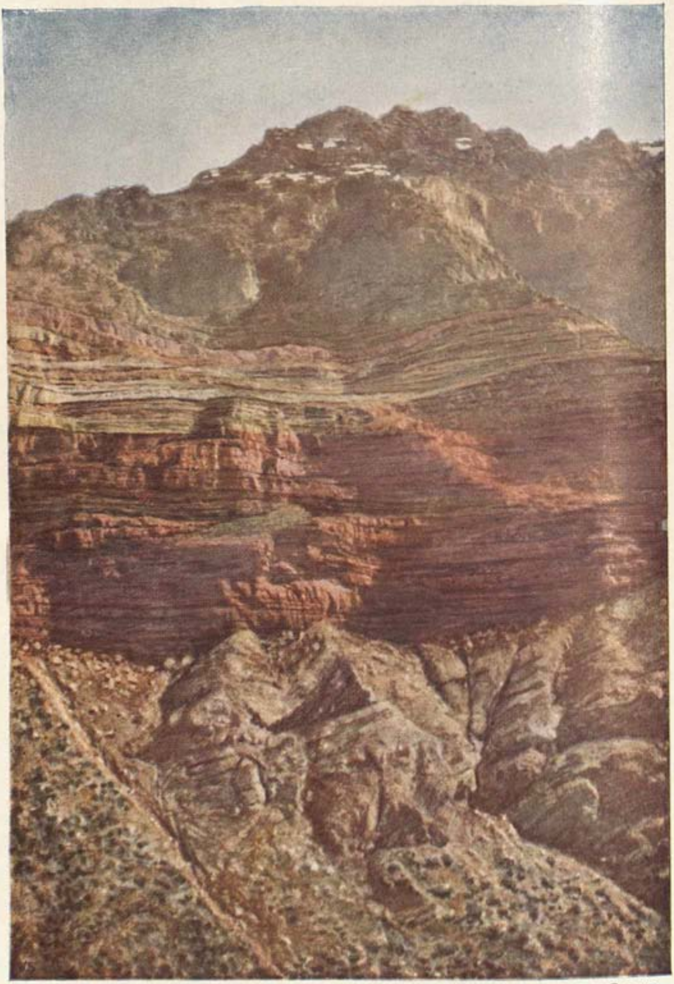
Volcanic Outbreaks in Scotland and N. Ireland.

Time wore on. The northern parts of these islands, so seeming fair and restful, were nevertheless being slowly undermined by a most insidious and powerful foe. It is probable that at that time the Hebrides had no existence, and that Ireland and Scotland formed a single land mass, whereon the same tranquil changes were slowly marked by Nature's tools as in the southern parts of Britain. Volcanic activity had been practically non-existent here for many ages; notwithstanding which, it was destined to break out, before the close of the Eocene, on a scale unparalleled here since pre-Cambrian times. The molten reservoirs forced a way up close to the surface, just as they do to-day in Iceland or Kilauea; and an immense number of small fissures formed in the crust, through which, at irregular intervals, great sheets of basalt flooded South-Western Scotland and the adjacent parts of Ireland (Plate 94). Probably, along the lines of fissure, small volcanic cones came and went; and there were, besides, at least five major volcanoes in existence; but of all these, nothing now remains but the stumps. The sheets of lava covered Mull, Skye, Staffa and the Western Isles, extending across to Antrim, where their denuded remnants form the Giant's Causeway. Northwards,

Pl. 78. *Q* 242.

Skull of a Canadian Flat-headed Dinosaur.

As the Cretaceous age progressed, the heads of these animals became progressively flatter, and their brains smaller. (c/f Plate 77).



Pl. 79. Q 243.

Precipice of Cretaceous Rocks in Peruvian Andes. (p. 232).

these disturbances had a great extension, over what was very possibly a continuous land mass, involving the Färoe Islands, Iceland and part of Greenland. These outbursts were marked as much by their long duration as by their lateral extent. At times, they seemed to die away altogether; and there was an interval sufficiently great for the barren surface of the lava to crumble down into soil, whereon plants took possession, to be followed in due course by animal life. Owing to the alteration of the river systems by the flows blocking up valleys, lakes were formed, and in them living creatures had time to germinate and flourish; the accumulation of their remains represents certainly hundreds, and possibly thousands of years. The plains of lava were carved into hill and dale; disguised beneath a green mantle, they might, at a casual glance, have had no existence. Then came fresh eruptions which started the ruin all over again. One of the most striking instances of the subsequent eruptions is to be found in the Scuir of Eigg, a ridge of rock some 1,300 feet above sea-level. The top of this ridge consists of the sides of an old valley formed by streams in the earlier lava. The gravel which formed the river bottom still remains, and some of its pebbles have been transported a considerable distance from their sources. As they vary in size up to boulders 2 or 3 feet in diameter, it is evident that the river carried a heavy volume of water, and was probably torrential in character. Lying above the gravel is a great mass of black glassy volcanic rock called pitchstone, which was obviously erupted after the valley had been carved out, and, taking the least line of resistance, had flowed down the stream bed to its present site (164).

"But volcanic activity, though it greatly altered the topography of the Western Highlands, was only a temporary phase of geological evolution. It filled up river valleys and otherwise changed the face of the land; but it did not arrest the progress of denudation. The processes of atmospheric disintegration at once began upon the cooled and solidified lava, and have been continued ever since. The result of the prolonged waste may be briefly summed up. The basalt plateaus which at one time no doubt not only spread in continuous lava flows up to the base of the Western Highlands, but even rose high along the flanks of the mountains and possibly stretched some way into the interior, have been so deeply trenched as to be reduced to a scattered group of islands. . . . So complete has been the change that the buried valley, under protection of the singularly indestructible pitchstone, now runs along the top of a ridge. What were once hills have disappeared, and what used to be a valley is now the crest of a lofty hill" (165).

The Continental Oligocene Lakes.

The continental mass of which our country at this time formed a part, stretched across Belgium into North Germany, the ocean then being on the south, and the Rhine Valley, in its upper part, being an arm of the sea, with its head at Mayence; into this estuary that great river flowed *southwards*. The elevation of the land at the close of the Chalk Age appears to have left a number of depressions, great and small, which became the sites of lakes or lagoons, according as the sea was partially or wholly excluded. The gradual evaporation and shallowing of the waters in the Rhine Valley led to the formation of the very valuable potash deposits of Alsace, which are estimated to be sufficient to supply the world's need of this fertiliser for 275 years (166). Elsewhere, the shallow waters became choked repeatedly with plants, and much lignite was thereby laid in store for human consumption. Sometimes this accumulation went on for thousands of years; so that we find at Zittau lenticles of lignite having a thickness of 163 feet. Everywhere the climate was sub-tropical, resembling that of the southern United States; and the lands were covered with many kinds of coniferous trees, and with laurels, cinnamons, magnolias, figs, birches, palms and others.

Fossil Resin of Königsberg.

The slow accumulation of the coal beds was interrupted by a temporary incursion of the sea, which swept the lagoons and marshes away, and for some time occupied much of Germany. A recurrence of land conditions in the neighbourhood of the Baltic, probably combined with heavy rainfall and large sluggish streams, caused the formation of great blocks or jams of timber, which accumulated particularly in the neighbourhood of Königsberg. Many of the trees forming these rafts were pines; and the exudation of the gum from them created the celebrated amber beds of that locality. In these sticky masses were caught countless unwary insects, besides many leaves—to such effect that no less than 2,000 species of insects alone have thus been preserved to science. It is a singular fact that man should be dependent for so much of his knowledge upon these accidents of Nature.

Beginning of Temperate Conditions in Germany.

After the sea once more withdrew from Germany, the climate cooled considerably, and the flora consequently took on a more temperate aspect. This was the real beginning in those parts of modern conditions.

France in the Oligocene.

During this age, a similar group of lakes formed in the Central Plateau region of France. But much of Provence was a part of the Mediterranean, and Paris itself the resort of oysters and other estuarine shellfish (Plate 88, B). In the mountains of the

Auvergne, a few volcanoes spat out ashy rubbish wherein was preserved a great collection of birds—owls, wagtails, woodpeckers, pigeons, rails, flamingoes, cranes, herons, gulls, cormorants and ducks. Some of the bird remains were actually found overlying their eggs, as if they had been asphyxiated by volcanic gases.

When we reflect on the differing nature and habits of these various birds, we can picture to ourselves how many-sided was that land, although its records are contained in but a few metres' thickness of rocks. Other reflections follow as a natural consequence. The sudden appearance of all these differing creatures is no mere freak. They all had an ancestry, extending back no one can say how far, but probably well into Chalk Age times.

Transformations in the Mediterranean: Nummulites.

We come next to the Mediterranean, which was destined, during this age and the next, to undergo some curious transformations. At the beginning it was a broad sea stretching from the Atlantic almost to the Pacific. At the close of Miocene times, it was, in its western part at least, a relatively narrow mass of tortuous channels between a number of low islands. Regarding it first in its marine aspect, we find that from the Maritime Alps, over the Apennines and the highlands of Greece, and from the Carpathians and the Balkans into Asia Minor, and thence through Palestine into North Africa on the one side, and through Persia and the heart of Asia to the shores of China and Japan on the other, there is one tremendous series of beds of marine limestone, largely composed of a special and relatively huge foraminifer—called, from its resemblance to a coin, Nummulites (Plate 85, *3*): hence these limestones are known as the Nummulitic Beds. The animals, the dead remains of which have thus come down to us, had a disc-shaped shell arranged in a spiral coiled around a single spherical central chamber. Sometimes these shells are as large as a florin, but as a rule they are smaller. The construction is peculiar, in that each revolution of the shell completely encloses and conceals from view all the preceding ones: pores and larger openings being the means of intercommunication between them. The animal itself was one of the simplest of organisms; yet, like many others of its class, it has left more enduring traces of its existence than the most powerful reptile or mammal.

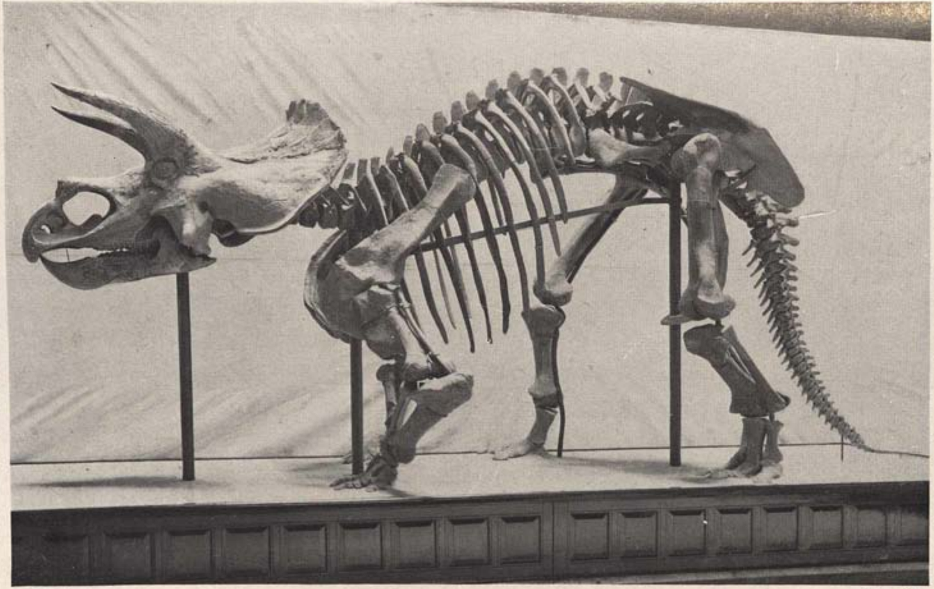
The present situation of these shells affords striking and unequivocal evidence of the changes which the Earth's surface has undergone since they lived in the clear waters of the swollen Mediterranean; for these animals, buried in their limy ooze, have been found at some of the greatest elevations attained by man—at 19,000 feet above the sea in the Himalaya (167), and high up in the Alps and Pyrenees. It is a peculiar commentary on human history that they were quarried in order to build the Pyramids of Egypt, while the Sphinx is cut out of a rock containing them!

Vast Elevation of Eocene Sea-beds.

Thousands of feet of the Nummulitic Limestone having been laid down, the sea eventually grew shallower; and the old cycle of changes, with which the reader must be more than familiar by this time, began once more. From the fringe of the Atlantic to the borders of China, there arose, at the close of the age, a long, relatively narrow chain of islands, which were destined to swell up in the next age, the Miocene, into the Pyrenees, the Alps and the Carpathians, the Caucasus and the Himalaya, besides a host of smaller mountains. As the land rose, enormous beds of conglomerate or puddingstone were formed on its shores in some quarters, especially in the Austro-Swiss region. Much of the coarse gravel forming these conglomerates is believed to have come from the Bohemian Highlands, which were snowclad at the time, and probably the sources of powerful glaciers. Farther to the east, in the Tyrol, marshlands and lakes were created by the elevation of the land; wherein vegetable matter accumulated, which has since been transformed into brown coal or lignite: one such bed at Häring has a thickness of 32 feet (168). To complete the medley of geographical conditions, the region bordering the plains of the Po, as well as part of the north Hungarian borderlands, was the scene of very considerable volcanic activity; while along the shores of the sea itself coral reefs grew luxuriantly, and in the clear waters lace corals, delicate in texture and wonderful in structure, and sea lilies abounded.

THE VIENNA BASIN.

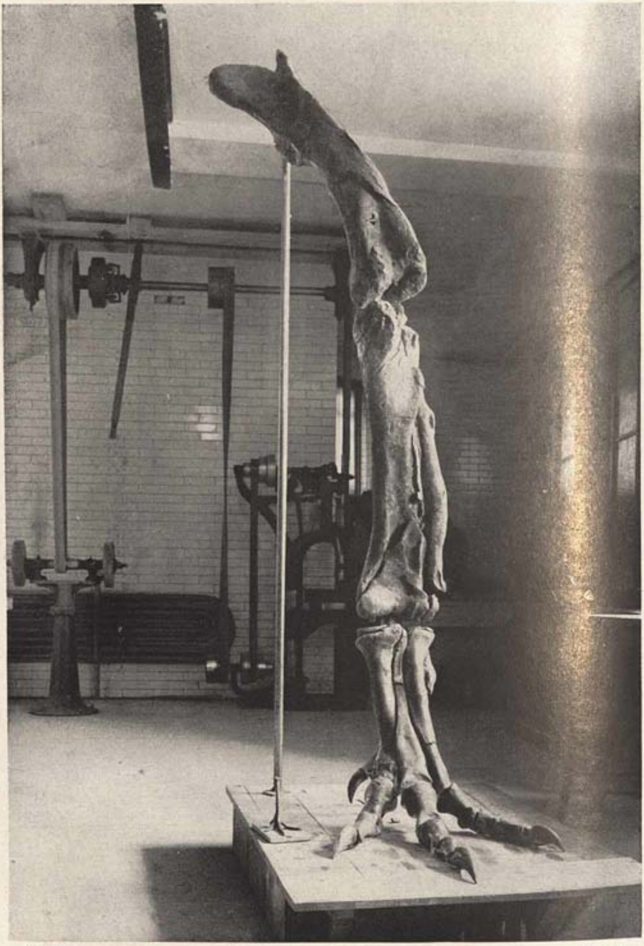
As the age wore on, the gradual withdrawal of the sea formed a great interior basin, in the heart of Europe, centring on Vienna and hence known as the Vienna Basin; this communicated at first with the main water body by divers channels, and had, besides, an enormous extension to the east, over the site of the Black Sea. Herein, in gradually freshening waters, was deposited a vast thickness of rock, entombing the remains of innumerable generations of animals and plants. A similar body of water covered much of Switzerland. The fossils stored up there in such profusion enable us to form a more or less complete picture of the times. An early Mastodon wandered in the higher parts; in the lower were to be found true rhinoceroses as well as some powerful allied creatures, now extinct (Titanotherium and Tinoceras, Plate 86). A host of smaller mammals sprang up in the grateful shade of the evergreen forest and in the long grassy meadows bordering the lakes and streams—opossums, rats, beavers, hares, hyænas, dogs, weasels, wolves and early horses. Primitive monkeys



Pl. 80. *R* 248.

Triceratops.

A powerful Horned Dinosaur of Cretaceous Age, bigger than a Rhinoceros, and equally pugnacious (p. 234).



Pl. 81. *R* 249.

The Leg of a Canadian Dinosaur (p. 233).

Gorgosaurus Libratus, 9ft. 6in. high.

swung from the trees. In the branches, and along the rush-strewn borders of the rivers, flocks of birds were to be found—parroquets, trogons, secretary birds, fowls, flamingoes, ibis, pelicans, marabouts and cranes; whilst up among the crags, in solitary grandeur, flew the lordly eagle. On the moors of the foothills, grouse abounded.

Oligocene Flora.

The flora, too, though still typical of a hot, damp climate, was becoming markedly modernised. Ferns, fan palms and feather palms crowded together in the wet lands; figs, alders, laurels and willows bordered the streams. Upon the hillsides oaks, birches, gum trees and many others probably formed a dense forest growth, with Sequoias at higher elevations. All these have left abundant impressions in the lacustrine mud.

Salt Pans in the Carpathians.

In the Carpathians at this time, among other interesting events was the creation of a series of natural salt pans, due to the evaporation of cut-off bodies of salt water; herein valuable beds of rock salt and gypsum were accumulated (Plate 93, A). Another economic event was the growth in many parts, particularly in Northern Italy, of beds of peat from the decaying vegetable matter; this is now worked as lignite.

Spain and Portugal.

Spain, in this age, continued a massif of old rocks; channels across the Pyrenees and Guadalquivir connected the Atlantic with the Mediterranean Sea. In Portugal there was a fairly considerable volcanic episode, whereby the land about the site of Lisbon was materially added to.

SLOWNESS OF ALL THESE CHANGES.

Among the many lakes that were formed by the receding sea waters, one of the most interesting was in the valley of the Allier, in Auvergne. This was a region of mineral springs and occasional volcanic eruptions—premonitory symptoms of a great outburst presently to come. In the rivers of this district, crocodiles and tortoises were numerous; and the eggs and bones of water-birds, and the skeletons of quadrupeds have also been found. The lakes, which were not large, filled up with exceeding slowness. Thus,

> "In the hill of Barrat, we find an assemblage of calcareous and siliceous marls, in which, for a depth of at least 60 feet, the layers are so thin that thirty are sometimes contained in the thickness of an inch; and when they are separated, we see preserved in every one of them the flattened stems of Charæ or other plants, or sometimes myriads of small Paludinæ and other freshwater shells" (169).

Another instance of the extreme slowness with which this age developed is furnished by the well-known Miliolite Limestone of Paris. This rock, which is much used for building, owes its name to the resemblance of its components to grains of millet: it is almost entirely made up of countless myriads of microscopic marine shells (Plate 85, *6*).

AUSTRALIA IN EOCENE TIMES.

Let us transfer ourselves to the East for a moment. We find Australia gradually assuming its present outline, but still very different from what it is to-day. In much of Victoria and New South Wales, marine conditions prevailed for a time, and in the early part of the age, the sites of Perth, Adelaide and Melbourne were all on the same ocean bed (170). There was later a wholesale withdrawal of the sea from Victoria, and the creation of numerous lakes and lagoons. Herein laurels, cinnamon, the sacred Ginkgo, and the beautiful broad-leaved fern, were entombed in the mud. Farther west, a deep clear sea extended well up over the border of the Great Australian Bight: herein chalk gathered.

NEW ZEALAND: RAISING OF THE SOUTHERN ALPS.

New Zealand, meanwhile, was undergoing considerable alterations. At the close of Cretaceous times, the Tasman Sea was a mass of high dry land, which may have been linked up to Australia, and was almost certainly joined to New Guinea and other islands on the north. The eastern fringe of the highlands was a maze of creeks and lagoons, wherein accumulated, for a very long time, beds of what is now true coal. The site of the Southern Alps had already received one uplift; and in this age it had another, on a much more elaborate scale. Great mountains were created, which were high enough to possess formidable glaciers. There was heavy and continuous rainfall; so that this one age presents the curious contrast of a large mountain mass being both created and destroyed. Towards its close, the mountains appear to have been depressed considerably, and in the long strip which forms the coastal plain and the foothills of Westland, the sea again took possession (171) (Plate 88, C); while the land in the Tasman Sea seems to have slowly foundered and rotted away. So, chip by chip and stone by stone, do we get at the modern topography; some features of which, as will be seen from what we have said already, stretch back into the immeasurable past, while others are but events of yesterday. It is interesting to observe that the North Island of New Zealand was already in the throes of that great volcanic activity which has never wholly ceased since. Considerable eruptions took place south of Auckland; and it was probably about this time that hot solutions from the molten interior commenced to carry up the gold which forms so large a part of the wealth of that district (172).

Emergence of Northern Africa.

Africa, during this age, also took a marked step towards its modern aspect; for at its close the great bays of the Mediterranean which had covered all its northern portion, as well as the waters which submerged Somaliland on the east and Nigeria on the west, all withdrew, leaving what seem to have been low grassy plains in some parts, and a tangle of marshes, meres and streams in others. Hereabouts, but particularly in Egypt, a wealth of new mammals developed. At the same time Nigeria possessed a huge flying bird, Gigantornis, with a wing-span of probably 20 feet.

Aspect of North America.

Finally, we come to the Americas. North America at this stage presents itself to us under three different aspects, at each of which we must glance briefly. The continent was at first considerably smaller than at present, owing to fairly wide strips along the coasts both of the Atlantic and the Pacific, as well as most of the southern States, being submerged. As already mentioned, however, there was, towards the close of the Cretaceous Age, a gradual emergence of the whole of the interior. The marine waters withdrew to north and south, and the rivers which had formerly drained inwards to these interior seas, now began to flow outwards to north and south, in pursuit of the retreating coast-lines: hence arose the drainage lines now occupied by the Mackenzie and Mississippi.

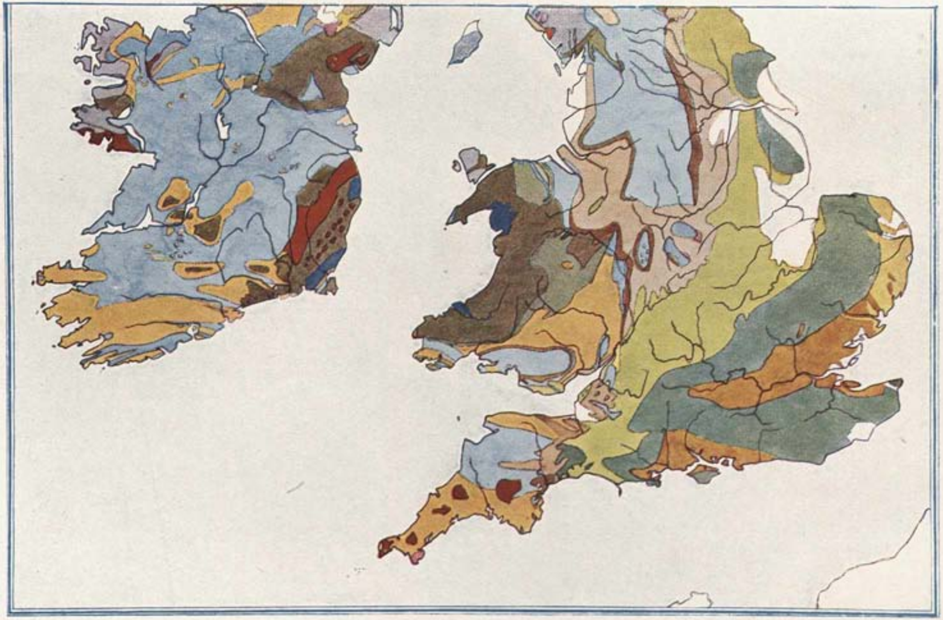
Creation of the Rocky Mountains.

The disturbances which created the Rocky Mountains and the many associated ranges had, of course, a profound influence in directing the south-eastern courses of the primeval Missouri,

Pl. 82. *R* 252

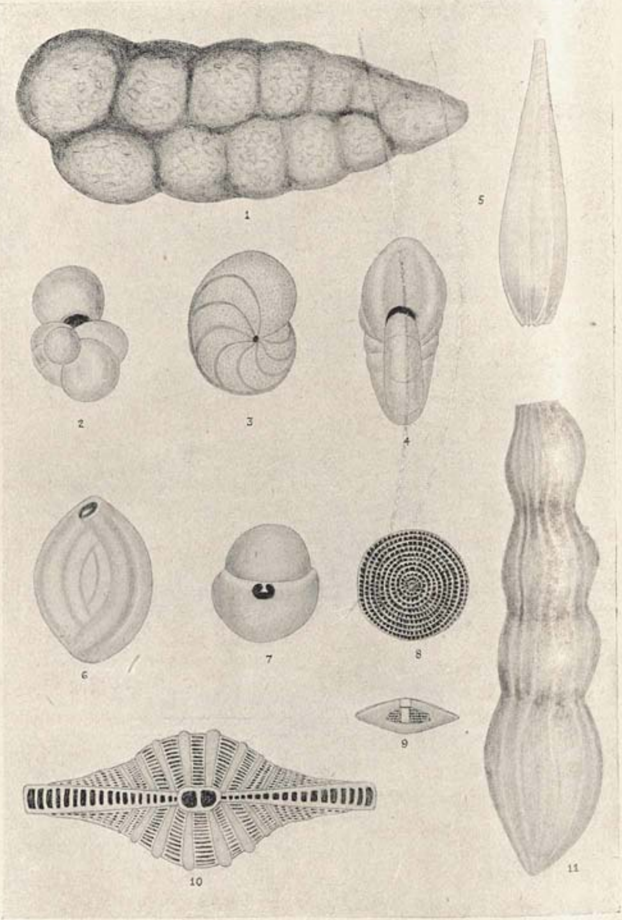
The skin of a Canadian Dinosaur. (p. 233).
(Chasmosaurus).


Recent.
Pliocene.
Eocene and Oligocene.
Cretaceous.
Jurassic.
Trias.
Permian.
Carboniferous.
Devonian.
Silurian.
Ordovician.
Cambrian.
Torridonian.
Undifferentiated pre-Cambrian, etc.
Granites, etc.
Lavas, etc.



Pls. 83-84.

Geological Map of the United Kingdom and Ireland.



Pl. 85. *R* 253.

Fossil Foraminifera.

1. Textularia (×15). 2. Globigerina (×40). 3. Truncatulina (×40). 4. Nonionina (×40). 5. Lagena (×60). 6. Miliolina (×60). 7. Biloculina (×20). 8. Nummulites. 9. Fusulina. 10. Lepidocyclina (×2). 11. Nodosaria (×30).

Platte, Arkansas and other streams. It will be remembered that the whole Pacific slope of the continent was a relatively weak area of the Earth's crust, wherein, during Cretaceous times, enormous deposits of mud and sand were laid down on a rapidly subsiding sea bottom, whilst alongside them equally enormous masses of granitic rock had just been forced up into the older rocks of Alaska and British Columbia. This weakness persisted into Eocene times. Very great internal stresses were set up west of the present site of the Rockies; and the rocks were upheaved, and forced into folds. The margin of the upheaved mass gave way under the strain, and was fractured in many places—one major fracture alone may cover no less than 3 degrees of latitude (173). Then the pressure from the west, which was apparently much the greater, forced great mountain masses thousands of feet thick to slide bodily over the immensely younger Cretaceous rocks which had just emerged above sea-level. These slips were probably in the nature of severe earthquakes, repeated at irregular intervals, each of which carried the displaced mountains a little farther to the east; but their cumulative effect was gigantic, for they are believed to have moved the mountains no less than 40 miles east of their original position (174). At about the same time, or immediately afterwards, huge bodies of molten rock, or magma, were injected into the practically horizontal rocks forming the western part of the Great Plains, with the result that numerous mountain masses—the West Elk Mountains of Colorado, the Henry Mountains of Utah, and many others—came into existence, being raised some 5,000 to 6,000 feet above the plains, and perhaps much more. The construction of these mountains is far from the normal mode of mountain building, and requires a special word. They form isolated heights in the same way as volcanoes; but they resemble the latter in no other particular. They have been proved conclusively to be formed by the injection between the layers of bedded rock of large bodies of magma, either as domes, as tabular masses, or as irregular bodies. The magma has forced its way in slowly, gradually raising the rocks above it into first a hill and then a mountain; in some cases fracturing them, and sending up dykes of molten matter to their tops; in other cases without ever reaching the surface. Subsequent erosion has worn these mountains down, so that all parts of their singular structure can be easily studied. The magmatic bodies themselves are known as *laccolites;* and the mountains they create are hence called laccolitic mountains (Fig. 7).

Associated with these phenomena is one of great practical

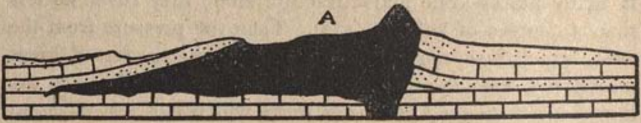


FIG. 7.—A laccolitic mountain: (A) the intrusive mass.

importance. The gases of the Earth's interior contain, beyond all question, large quantities of volatilised gold, silver, copper and other economic minerals; and when the laccolitic mountains were formed, these vapours started forming deposits on the walls of fissures and even replacing easily alterable rocks like limestone. To this fact is due much of the immense mineral wealth which has been extracted by the Americans from the Middle West.

THE CALIFORNIAN GOLD GRAVELS.

To the west of this disturbed region, another set of changes was at work. The Sierra Nevada, which had been a mountain range throughout Cretaceous times, was, of course, being slowly worn away, and a large and complicated series of streams covered its flanks. Into the gravels of the stream beds, vast quantities of gold were swept from the weathered and crumbling surfaces of veins; accumulating there for ages, these gold fragments built up the placer deposits which caused the Californian gold "rush" of 1849. This region has been a continuous producer of gold ever since, although it passed its maximum over forty years ago. From 1,200 to 1,500 millions of dollars have been won from there in all, of which about a quarter has been proved to come from these old stream beds (175). Much gold still remains; but, owing to prohibitory legislation, it is difficult to mine it at a profit.

The Sierra Nevada presents to the east a singularly abrupt slope, rising from the plains at its foot just like a great cliff. This is a line of fracture; and during the age with which we are dealing, this cliff probably received its first upward impetus. But there was then nothing like the mighty range that now confronts the traveller. "Gradually the mountains were reduced to gentler slopes, and the canyons widened to valleys. Meandering among longitudinal ridges, the rivers flowed from low divides to rolling foothills, and the whole slope was clothed in the dense vegetation of a damp, semi-tropical climate" (176). The precipices of to-day were formed by slow upward jerks or earthquakes, rising perhaps only a few feet at a time; but so long-continued was this work, that a great mountain barrier was at last created, sloping east to the Great Basin at a very sharp angle, and west to the Pacific at a more moderate one.

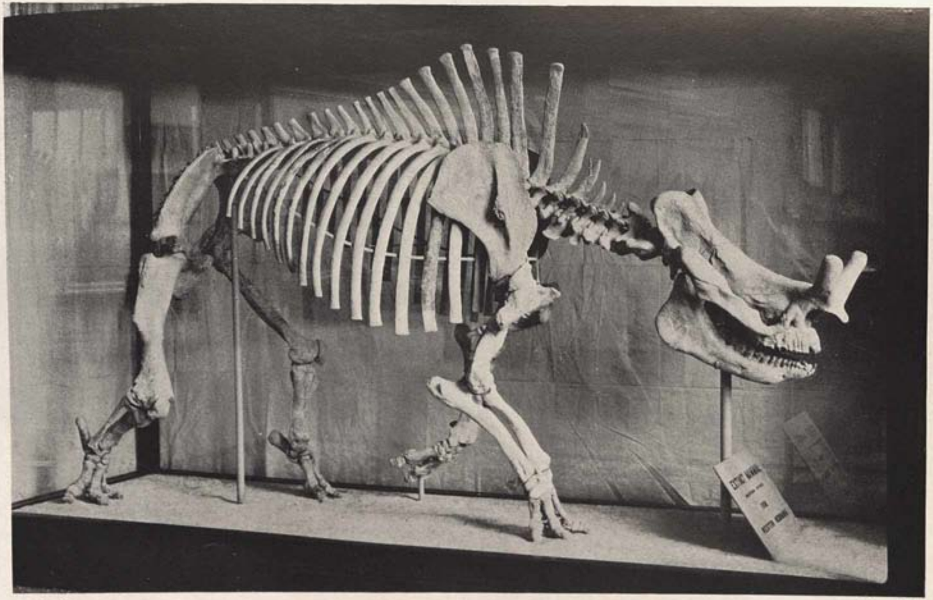
Volcanic Eruptions.

Farther west still, as well as to the northward, in Vancouver Island, a long narrow trench was formed, both on the land surface and in the sea-bed; in the one, great thicknesses of fluviatile rocks accumulated, and in the other, still thicker bodies of marine sand and mud. The total deposition of the latter in this age (Eocene and Oligocene) was no less than

39,000 feet (177), of which the first half represents many varied conditions, with occasional volcanic outbursts, and the latter is the record of a constant, moderately deep sea. Late in Eocene times, volcanic "episodes" were unpleasantly common along this coast. A series of lava flows and ash beds, at least 5,000 feet thick, was built up into what are now the jagged peaks and frowning precipices of the Skagit Range; and with rather less violence, this continued all the way to Alaska, where there is a formidable pile of similar rocks in the Wrangell district. Meantime, out at sea over the site of southern Vancouver Island, a great submarine platform was built up of volcanic materials, on top of which lava cones gradually rose above the waters; their grey and black sides, rising in majestic curves above a narrow fringe of vegetation on the shores, must have formed as pleasing a spectacle as any of the time. These eruptions, both marine and on land, were sometimes of great violence, but more frequently not at all spectacular (178); the lava sheets were not infrequently hundreds of feet thick; and the ash and dust from the eruptions was blown by winds or carried by streams far to the east.

The Great Plains of America come into being.

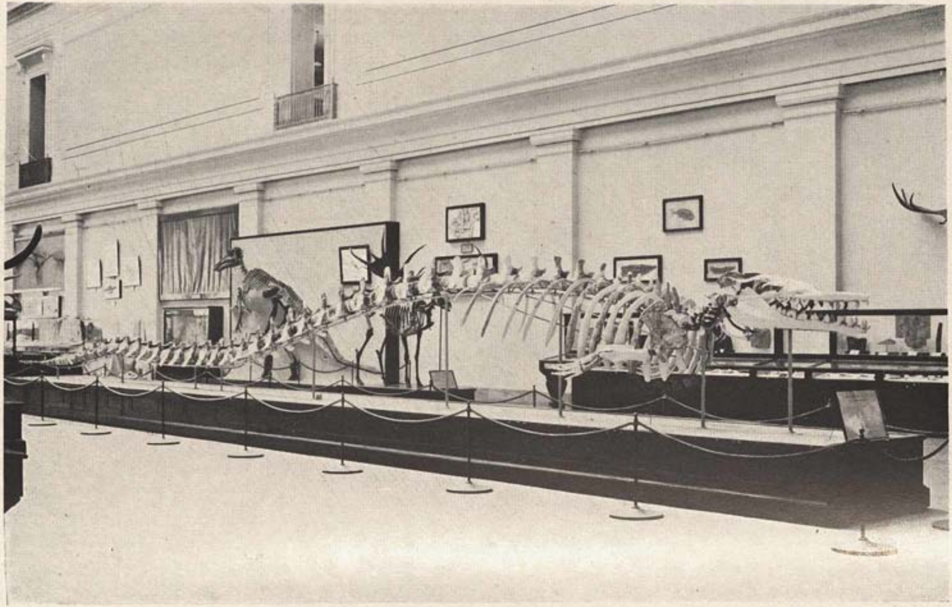
After the Rocky Mountains had attained a goodly elevation above the sea, they had on their eastern side a long, more or less flat plain, generally similar to the Great Plains of to-day, but with the important difference that it possessed an abundant rainfall and consequently a dense evergreen cover. The rivers appear to have been long, broad and sluggish, and to have flowed in wide valleys wherein they constantly altered their courses, just as the Missouri and others of the same region do to-day. "The divides between the streams were not high enough to prevent flooding during high water. The whole country was virtually a great flood plain, on which accumulated



Pl. 86. *R* 256.

Titanotherium.

An early Tertiary Ancestor of the Rhinoceros. This clumsy creature was sometimes 15 to 18 ft. long.
(pp. 248, 257).



Pl. 87. R 257.

Skeleton of a Zeuglodon.

An Eocene ancestor of the whale, 55 feet long. Atlantic and Mediterranean (p. 242).

the sediments that the rivers brought from the mountains. With these sediments occur beds of pure volcanic ash which must have been carried by the wind or floated by the streams for long distances. The volcanoes that had been so active in western America during the Eocene epoch had not ceased their eruptions—indeed, they have not yet become entirely extinct, as is testified by the recent outburst of Lassen Peak, in Northern California" (179). In the morasses formed by these rivers, great numbers of animals perished, and their remains are literally fossil graveyards. A similar state of things exists to-day in the wildernesses of the upper Parana, where "every year a plain of some 60,000 square miles is converted during the rainy season into a labyrinth of lakes, ponds, swamps, channels and islands. On these islands the animals gather, and great numbers of them perish" (180).

Animals of the Age.

Upon these lands, many and strange mammals wandered. Besides the lists we have already given, there were camels, insect-eaters and sabre-toothed cats—the last of which afterwards developed into the formidable sabre-toothed tiger. Hog-like animals were numerous, and some of them very large and curious. Some creatures were merely fantastic. For instance, one large family, Protoceras, "were deer-like creatures about the size of sheep. The head of the male was grotesquely ornamented with short bony protuberances and large, scimitar-like tusks. Each front foot had four toes, and each toe had a hoof like that of a deer or antelope" (181). The lord of the age was a clumsy, rhinoceros-like creature, as large as an elephant, called Titanotherium (Plate 86); but although protected by the most formidable of hides, this creature failed to survive for more than a very limited period. It had on the front of the skull a pair of great bony horn-like protuberances. Its head was long, large and of bizarre shape, and the thick bones of the skull protected a ridiculously tiny brain. It probably charged blindly at all and sundry when infuriated, just as the rhinoceros does to-day.

VAST DEPOSITS OF LIGNITE.

The river, marsh and lake deposits of this region attained a very great thickness—over 10,000 feet in places. Throughout the very long time of their creation, the climate appears to have been semi-tropical and humid, and the vegetation abundant; consequently, great beds of lignite are common in these deposits. It is estimated that in North Dakota alone there are nearly 700 thousand million tons of this dead plant life in beds over 3 feet thick, besides an enormous quantity in thinner beds. If this could be gathered together into one mass, it would cover an area as large as England to a uniform depth of some 13 feet. Of the plants whose remains went to form it, those possessing popular names were sensitive ferns, chain ferns, redwood trees, the cypress, the cedar, maidenhair trees, fan palms with leaves 5 or 6 feet wide, figs, elms, maples, birches, alders, poplars, willows, oaks, hazelnuts, walnuts, sycamores, dogwood, hickory, box elder, buckthorn and horse-chestnut. And, lest it be thought that this indicates an extraordinary variety in the vegetation, it must be remembered that a Dutch botanist collected, in an area of 3 square kilometres, in a small island off Java, no less than six hundred different species of trees (182)—so wonderful is Nature in her variety!

Another great gathering ground for plants during this age was the eastern and south-eastern part of the continent. It must be explained that at the beginning of Eocene times, the coast-line was many miles inland from the present shore, being under the shadow of the Appalachian heights. At their southern end, it curved across the State of Georgia, and made a wide northward sweep up the Mississippi Valley, as far at least as Cairo, then back again across Texas and Mexico, roughly paralleling the present Gulf. Florida, at this time, was out at sea, and was well submerged. All along this coast, beaches, spits and lagoons ran, in appearance not unlike those presently existing in its southern parts; and in them many plants were buried.

There was, during part at least of this age, land connection between North and South America; but it is very possible that towards its close there was a strait giving water connection between the Atlantic and Pacific Oceans.

South America.

As to South America, its most interesting part at this time appears to have been the wide area of Patagonia, much of which was a land surface, whereon dwelt numerous curious animals, long since extinct, at which we may find space to glance in another chapter. In the eastern part of Brazil, the provinces of Bahia and Pernambuco were largely beneath the sea; while on the other side of the continent, the mighty barrier of the Andes had not yet been created, though its birth was imminent. The terrestrial weakness of the Pacific mountain regions in North America extended here likewise; enormously thick bodies of Eocene rock being laid down in Peru and Ecuador.

It was at about this time that Antarctica, still enjoying a mild climate, may have had its greatest extension to the northward; but very little is known about it, and it is far from certain that it ever formed a part of the American lands. The rocks of Graham Land, however, are remarkably similar, in situation and nature, to those of the Southern Andes.

CHAPTER XI.

The Age of Mountains (*Miocene and Pliocene*).

VARIATIONS IN GRAVITY.

IF a pendulum be set in motion on the seashore, it will make a certain number of complete swings in a given time. Let the same pendulum be taken to the top of a conveniently near mountain, and it will be found to make fewer swings in the same time. Finally, if it be then transported to the bottom of an equally conveniently situated mine, it will be found to make more.

This variation is due to the effect on the pendulum of the Earth's gravity attraction, which increases the nearer one approaches to the Earth's centre. But in certain localities the pendulum does not swing as it ought to, making either fewer or more swings than the theoretic number, in response to some hidden influence. The latter is ascribed, with every probability of truth, to variations in the Earth's density at those places; in other words, some spots on the globe are lighter and others heavier than, theoretically, they should be. As examples of places where the density is greater than the normal, we may mention Melbourne, parts of New Zealand, and South Victoria Land; while of those where it is less, large tracts in India, together with numerous isolated spots in Siberia and a few in the United States, may be cited. These variations in the Earth's density are believed to be definite symptoms of unrest in the crust; and if this be really so, then hardly anywhere would a pendulum have swung correctly in Miocene times, when earth disturbances were universal.

Relatively Modern Origin of the Alps.

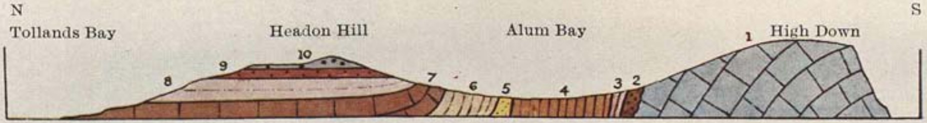
To the casual traveller, wandering among the valleys of any greatly upheaved mass of land, such as the Alps, it may seem almost incredible that the many peaks, differing in outline, in height and in dimensions, should ever have been united; or if they were, that the deep canyons and jagged precipices which may be observed on every hand, are anything but the results of some natural convulsion, compared with which the most severe modern earthquake is as but the shaking of a table-cloth. But nothing is more certain than that, in nearly every case, these rugged mountain areas once formed flat or undulating lands, and that prior to that time they were beneath the level of the sea (Plates 91, 95, A). By patiently tracing and separating the tangled strata, the geologist is enabled to say how the heights were originally built up, grain by grain, of sand, mud or lime; producing, in many cases, fossil remains as the irrefutable proofs of his contentions. By noting every twist and bend in the direction of the rocks, he outlines their original distribution, the nature of the movements by which they have been disturbed, and the directions whence the disturbing forces acted. Pitfalls confront him at every step. Profound faults may lower the beds he is tracing by thousands of feet, leaving him mentally, and sometimes actually, on the edge of a precipice; gigantic convulsions may twist the beds into the semblance of a wrung towel, so that their constituent minerals are altered and hardly recognisable: yet, by a sufficiently detailed study, out of all the chaos an orderly succession of events may be deduced. Applying such principles to the Miocene mountains, let us see what they show us.

Aspect of the World before the Miocene Mountains Arose.

At the close of the Oligocene Age, the globe was much in the condition of a monster that has suddenly arisen out of the deep, sufficiently far to be quite noticeable, yet not far enough to drive the pools of water from the creases on its back. The budding Alps formed a string of long, low, relatively narrow islands. The Pyrenees were merely the foreshore of Spain, and a part of them, even, was a marine strait cutting off that country from France. An interior sea stretched all the way from Austria to beyond the eastern confines of the Caspian: disconnected lands separated it from the Mediterranean. At this time, the southern front of the unborn Himalaya was a region of great crustal weakness, on the western side of which, in Sind, a combination of rapid uplift in one district and equally rapid subsidence in another, had already laid down a thickness of many thousands of feet of rocks, all of fluviatile origin. Most of the long chain of the East Indies was submerged. Far away in South America, the great longitudinal plateau between the eastern and western Cordilleras, now 12,000 to 14,000 feet above the sea, was then a marine channel, the waters of which extended beyond the site of Lake Titicaca; the mountains bordering this channel were relatively insignificant. At home in England, the Chalk hills which form so distinctive a feature of the southern counties in general, and the Isle of Wight in particular, had as yet no existence, though their course was probably defined. We mention these scattered places just to show that the Miocene mountain-making forces had a clear field to work in.

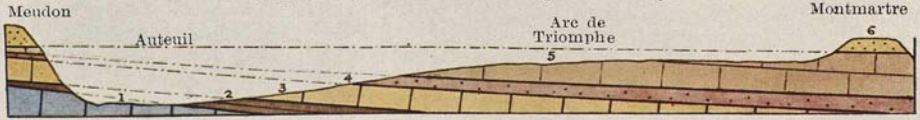
Theories of Mountain-building.

Of course, none of the many theories of how mountains are created can be proved, except by deductive processes of reason-



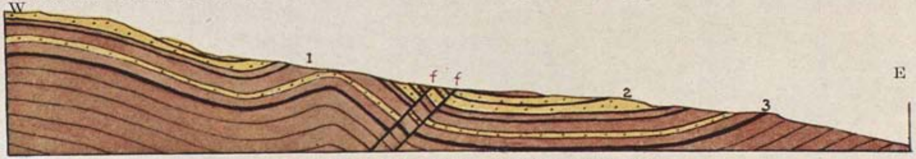
A: The Isle of Wight (after Bristow).

1. Chalk. 2. Woolwich and Reading Beds. 3. London Clay. 4, 7. Bagshot. 5. Bracklesham. 6. Barton. 8. Headon. 9. Osborne. 10. Bembridge beds and Drift.



B: Paris (after De Lapparent).

1. Chalk. 2. Plastic Clay. 3. Calcaire Grossier. 4. Beauchamp Sands. 5. Gypsum. 6. Fontainebleau Sands.



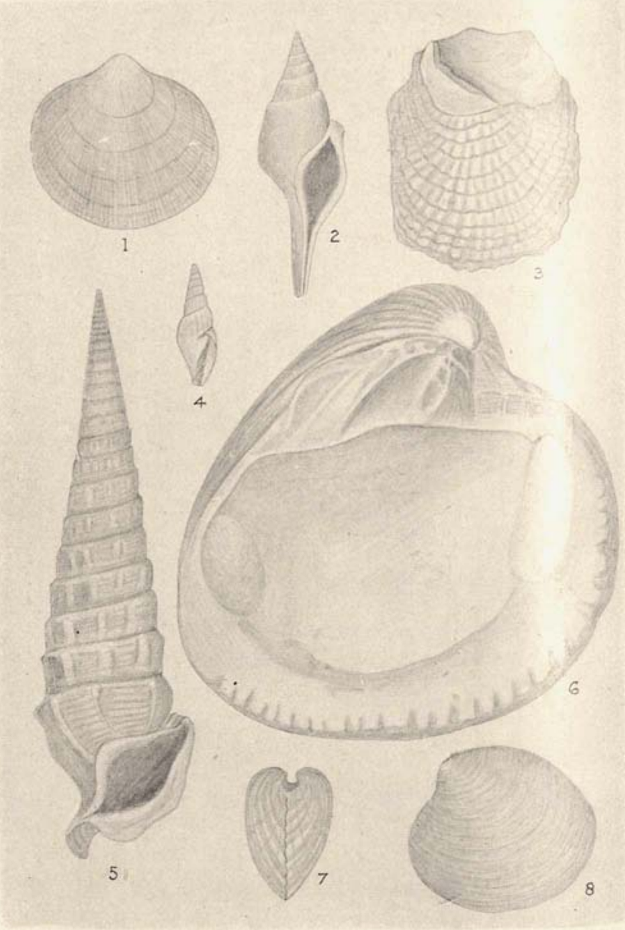
C: Greymouth, New Zealand (after Morgan).

1-3. Eocene. 1. Shale. 2. Sandstone. 3. Coal Seams. f.f. Faults.

Pl. 88.

S 262

Sections through Eocene Rocks.



Pl. 89. *S* 263.

Eocene Shells. 1. Pectunculus. 2. Fusus. 3. Ostrea. 4. Mitra. 5. Cerithium. 6. Venericardia. 7. Cardita. 8. Cytherea.

ing, and they are, therefore, all subject to a certain amount of just suspicion: nevertheless, deductions based on the structure of existing mountains do go very far towards showing how they are made. The following remarks apply only to *folded* mountains; for of course, mountains may arise by denudation also.

Now, wherever deep oceans and high lands adjoin, experience shows that earthquakes and volcanic disturbances must be looked for; and it has already been explained that in such regions the molten magma very possibly approaches much nearer to the surface of the Earth than elsewhere, thereby upsetting the crustal equilibrium. If it be assumed (and there is nothing to indicate the contrary) that this really is the case, then we can, for the purpose of the present book, reduce the problem to a simple little matter of mechanics. That part of the Earth becomes a fluid or semi-fluid mass, with a heavy solid crust on top. By the irregularity in the line between fluid and solid, the depressions into which the latter sinks and the elevations into which the former rises both become liable to motion, according as the loads which they are carrying—*i.e.* the solid crust above—increase or decrease. Now, at the surface itself, the agents of denudation will be all the time transporting matter from the heights and dumping it into the abysses; so that the hollow will tend to sink still farther and the height to rise still higher, in response to the pressure of the molten magma. Thus, between the points of greatest rise and greatest fall, a serious and constantly increasing strain will be initiated; until, in the effort to correct these abnormal conditions, the undermost part will drive in upon and press up the other. This pressure comes, of course, from the lower or seaward side, and to that extent the theory, which is that of the Rev. O. Fisher, complies with observed facts, as in all the mountains now under review the pressure has come from the seaward side. The results of this pressure are expressed in the folded and contorted rocks that form mountain ranges.

If the rocks are not too hard, and are fairly uniform in strength, then they will be forced up into a series of graceful folds. If very hard and very soft beds alternate, there will be a tendency for the hard layers to be driven forward bodily over the soft ones. If immovable obstacles, such as great bodies of ancient hard rocks, happen to be in the way, then such overthrusts will almost certainly occur, and the folding will be sharply angular: there will also be a lot of crushing and mashing, and new minerals will be formed out of the wrecks of the old ones.

As will be seen from the diagrams (Plate 95), mountain folds of all these kinds were created in Miocene times. That the overthrusts and crushings were much greater in the long Eurasian disturbance than elsewhere, is due largely to the fact that many knots or cores of hard crystalline rocks opposed the pressure: of these, the mountainous core of Central France, Spain, Bavaria, Bohemia, the mass of the Rhodope Mountains, and the Deccan Plateau may be cited as examples. When the pressure came, these ancient rocks acted as buffers, against which the younger rocks strained and strove with useless fury. The movements may be likened in fancy to those of the waves of the sea; in long curved lines in *échelon* formation, they burst upon the devoted lands with a resistless might, the results of which exaggerate its actual strength. For in reality, the movements were probably so slow as to be hardly recognisable; and we must, for many reasons, regard the tangled knots of mountains that now confront us as the result of a quiet but constant pressure applied throughout many, many thousands of years; with no indications of its action except the slow uprising of the land, an occasional severe earthquake and, perhaps, the intermittent ejection of lava streams through cracks and fissures. Moreover, although the results became evident in Miocene times, the process had really been going on much longer.

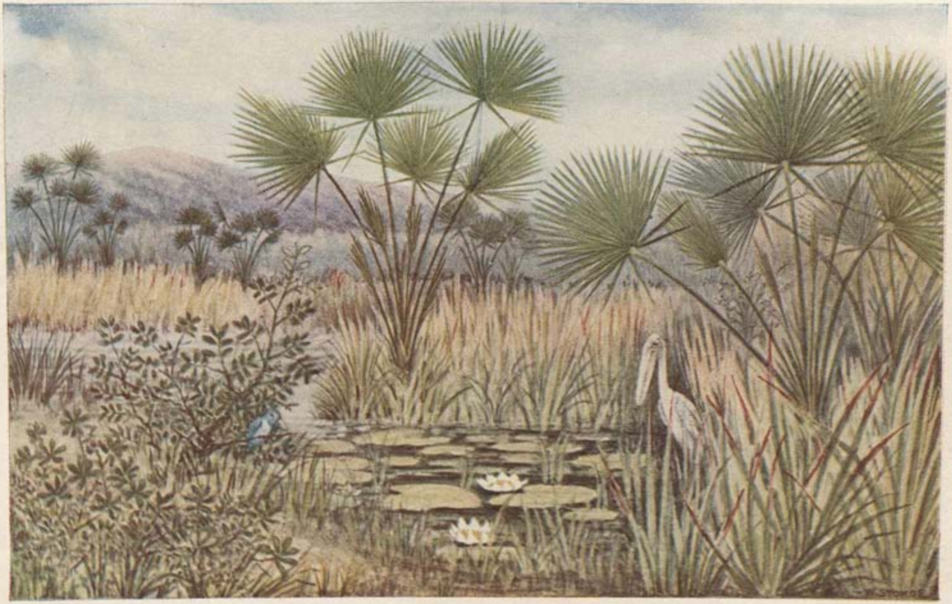
ELEVATION OF THE PYRENEES (Plate 95, C).

Coming to the disturbances in detail, let us consider those of Eurasia first. It appears probable that the area primarily involved was that of the Pyrenees, which, from a low foreshore, largely composed of the dead bodies of Nummulites that had lived in the preceding age, gradually rose into the semblance of a long narrow east-to-west ridge. Somewhat complicated in its central part, the range is exceedingly simple in outline on its western and particularly on its eastern side. The general level of the mass is about 8,000 feet above the sea, whence a number of peaks rise to 11,000 feet or so: two of the highest, Monts Perdu and Vignemale, have summits composed of the same Nummulitic limestone which in Eocene times formed the bed of the Franco-Spanish sea. The steeper side of the chain faces Spain, and for long stretches is almost impassable, except by tortuous footpaths. From the central ridge, numerous transverse ridges descend in herring-bone fashion on both sides towards the plains, having between them narrow gorge-like valleys in which can be traced the handiwork of glaciers that have long since melted away. These ridges become narrower and smaller the farther they recede from the central mass, until they merge into the foothills and the plains themselves, at distances of from 10 to 40 miles. If, now, we were to fill in each of these valleys with the rock which has been excavated from it by avalanche, frost, wind, glacier and stream, we should get a true conception of the original appearance of the chain. Great though the change may seem from such smooth slopes and even skyline to the massive peaks and rugged glens that now confront us, yet we must remember that it is immensely less than the changes that are not less clearly shown by older rocks: where, in many a cliff or railway cutting, we may see the stony record of a whole series of ages bevelled away to a gently sloping plain, ere ever a grain of the rock which is superposed upon it was deposited.

The Pyrenees are about 270 miles long; but their line is continued westward for an equal distance by the adjacent chain of the Cantabrians, which may be considered as a part of the same great mass. But while the one, with its well-nigh impassable mountain wall, has ever been a barrier and a hindrance to the growth of civilisation, the other, with its rich deposits of coal and iron, and its proximity to a number of good harbours on an oceanic shore, has played no inconsiderable part in the economic development of the Peninsula.

Elevation of the Alps (Plates 91, 95, a).

The next effort of the Miocene mountain-making forces was in the Alps, whose various ranges, curving to all directions of the compass, and each a most severe geological problem in itself, now had their greatest uplift. The major pressure was undoubtedly from the south-east; and the sea and lake beds of Eocene and early Miocene times were thrust northwards bodily. Owing to the intense resistance afforded by the massif of old rocks in Bavaria, the rising beds were folded, fractured and even obliterated in the most extraordinary manner. This is particularly well shown in the Bernese Alps and the Jungfrau (Plate 67), where rocks of several ages have been twisted and torn about like so much putty. The thrusting forward of great masses of old rocks over younger ones, of which our own Scottish Highlands afford an outstanding example, was here displayed on the grandest scale. The intense compression not only raised the land high in the air, but also changed the nature of the rocks over vast areas, from soft sediments to hard crystalline schists. The continuance of the pressure on rocks that were already closely folded caused the lower parts of the folds to



Pl. 90. *S* 266.

An Eocene Landscape (p. 240).

Much of Southern England, especially near Bournemouth, resembled this.

Pl. 91. *S* 267.

Rosenlaui and the Wetterhorn (12,146 ft.).

One result of the Miocene Mountain-making movements (cf. Pl. 95A).

Photo. Wehrli, Kildeberg.

pinch in, and the upper parts to open out, after the manner of a fan. It is the centres of these "fans" which now form some of the highest summits.

THE APENNINES AND THE JURA RAISED.

At a somewhat later time, the minor ranges of the Jura and the Apennines came into being. The site of the Jura had long been a zone of weakness in the crust, as is evidenced by the numerous alternations of freshwater, marine and lacustrine rocks that accumulated in the immediately preceding ages (Plate 55, C). The Jura Mountains form an offshoot of the Alps, separated from the main chains by the Rhône, and folded at a tangent northwards; according to Collet, much of their development occurred during Pliocene times (255).

In the Jura there is a regularity of structure which can best be compared, perhaps, only with areas outside Europe, such as the ancient Appalachians. It is composed of a great number of overlapping parallel ridges—at least 160 have been counted—forming, in the main, a regular series of folds. Although overthrusts and contorted rocks are not very conspicuous, yet there are a considerable number of fractures; the land on the French side of the chain having, on the whole, subsided, while the chain itself has gone up. The total compression here was about as great as that of the Appalachians in far earlier times, averaging one-third to one-quarter of the original width (183).

The Apennines, which may have commenced to grow a little earlier than their northern analogue, continued the operation to a much later date; for, from the plains of Liguria to the shores of Sicily, marine rocks which were deposited at the base of the new mountains during late Miocene and Pliocene times, now stand over 3,000 feet above the sea, forming the foothills, or Subapennines. On the western side of this chain vulcanism broke out, on a considerable and long-enduring scale: this was almost the only manifestation of such a nature that the disturbances had so far produced.

The elevation of all this land could only take place at the expense of the sea; and the Western Mediterranean now had to play a very restricted rôle indeed, although it was never entirely obliterated. Part of the land foundered, thereby creating the Tyrrhenian Sea.

Elevations in the Near East.

Continuing east, we come to the Dinaric Alps, which also now had their uplift; rising as a series of long, parallel, folded ridges trending north-west and south-east, and so defining the eastern side of the modern Adriatic. Here also, and especially on the Serbian frontier, lava streams poured over the surface, while dykes of molten matter forced a passage through and between the bedded rocks.

In North-east Greece and Thrace, the movements partook more of the nature of folding and fracturing, followed by depression, than of mountain-building. In fact, on the southern borders of that wild region, the faults that bound the Gulf of Salonika and the base of Mount Athos, point to the foundering of the greater part of the land which up till then had occupied the Ægean Sea; the amount of this down-warping was not less than 10,000 feet, or nearly 2 miles (184).

The disturbances passed under the site of the Bosphorus—then non-existent, but destined in Pliocene times to become a river valley draining probably northwards into the Black Sea, ere it took up its modern function of a marine strait (185). In Asia Minor, a large number of rift valleys—*i.e.* valleys bounded wholly by faults, the enclosed space having been let down more or less bodily—testify to the activity of the same great forces as, under different conditions, were contemporaneously building up the Alps.

Rise of the Caucasus and Elburz Mountains.

Further east still, a magnificent range, surpassing even the Alps, was built up in the Caucasus (Plate 55, B). 750 miles long and 150 miles wide, with its greatest peak rising to 18,500 feet above the sea, with hundreds of great peaks of lesser magnitude, and with glaciers, ravines and torrents galore, this mighty mass yet had little if any existence prior to Miocene times, for the Tertiary sediments are involved in its uplift, just as they are farther west. Its creation was followed by a great outburst of vulcanism, lava and ashes being ejected from many centres. The greatest remnant still existing of the old centres of eruption is also the highest point of the range, Mount Elbruz. It is only a step from the Caucasus to the south of the Caspian Sea, where we find, stretching for 450 miles in a great arc, another mighty range, largely volcanic, of the same age and with the same general history: the Elburz Mountains. Here also the peaks soar up to a height of 18,500 feet, the great ancient volcano Demavend just exceeding that figure. The internal fires are not yet wholly extinguished in this region; for Demavend still continues to emit volcanic gases. Another, and far more celebrated focus, from its Biblical associations, is the stately cone of Ararat (16,925 feet), in Armenia.

To the south of the mountain sites, in early Miocene times, lay a wide expanse of sea. Later on, however, the Makran coast and eastern Persia emerged; and still later (in Pliocene times) the rest of the land came up, some of it as far as 9,000 feet above the sea (186).

Rise of the Himalayan Ranges.

Still we travel east, and still new mountains meet our view. Beyond the howling wilderness of Seistan, beyond the gloomy gorges of Afghanistan, lies the greatest by far of the Miocene creations in the old world—the mighty Himalaya. Like the Pyrenees and the Alps, the Himalaya had but recently been the site of the Nummulitic sea; and the same unequivocal proof of its elevation was supplied by the coin fossils themselves, specimens having been found as high as 19,000 feet above tide. There is a great tangled knot of mountains in Kashmir, whence trend east and south-east two or three nearly parallel ranges for more than 1,500 miles; all these are collectively known as the Himalaya, but vast stretches are still little known geographically, and far less from a geological point of view. It must suffice, then, to say that a general movement of elevation began by the shallowing of the sea in Eocene times along the whole northern border of Peninsular India. Then came a general emergence in Miocene times; and before the Pliocene the mountains were not markedly dissimilar in height (though much less denuded) from their present aspect. Along their southern front ran a great line of weakness and fracture; south of this the plains of the Ganges and the Indus subsided, north of it the mountains rose still higher, until they attained the massive wall-like appearance that they have to-day. The barrier to routes of travel is sufficiently bad for passes 18,000 feet above the sea to become main roads; and the jagged peaks which rise above those passes, and which have a sharpness of outline not to be seen elsewhere in the world, may be counted by hundreds. North of this stupendous mountain wall lies the Tibetan Plateau, 15,000 to 18,000 feet above the sea. It comprises seven or eight long latitudinal chains, the valleys between which often have no outlets. North of this is the Tarim—Tsaidam depression; and beyond that the Tian Shan,

Pl. 92. *S 270.*

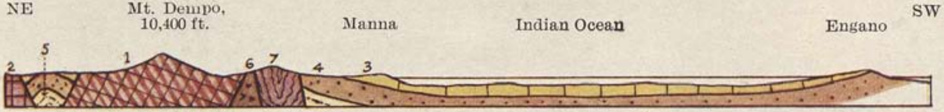
Mt. Rainier, Washington (14,444 ft.).

One of the youngest mountains in the world (p. 283).

Photo. Asahel Curtis, Seattle.

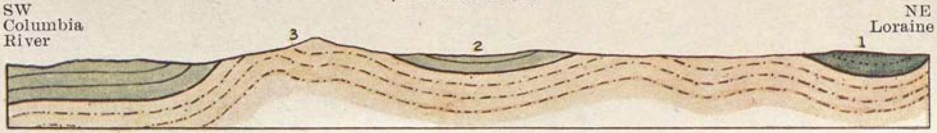
A: Carpathian Mts. near Targul-Ocna (after Teisseyre).

1. Terrace Gravels, etc. 2. Miocene Salt. 3-5. Oligocene Sandstone, &c. 6. Eocene Salt formation.



B: Southern Sumatra (after Schmidt).

1. Recent Lava. 2. Tertiary Lavas. 3. Pliocene and Upper Miocene. 4, 5. Middle and Lower Miocene. 6. Granite. 7. Ancient Schists.



C: Mouth of Columbia River, Washington (after Weaver).

1. Upper Miocene. 2. Middle Miocene. 3. Eocene.

Pl. 93.

Sections through Miocene Rocks.

etc. All these mountains participated in the Miocene uplifts. Great faults might be expected to be (as they are), a feature of Himalayan structure; for instance, in both the Siachen and Baltoro glaciers, two of the largest ice rivers in the world, we find the rocks on the opposite sides quite different. A tremendous fracture also separates the south side of the chain from the Indus-Ganges plain.

Other Uplifts in Asia.

At the same time the Hindu Kush, the Karakoram, the Altai, Kuen Lun, the Tian Shan, and the mountains fringing northern Mongolia, all underwent uplift. The force creating the Himalàya moved from north to south, but practically nothing is known of its direction in the Tibetan ranges. An important offshoot of the same disturbances created, at right angles to the Himalaya, the vast mass of parallel chains that cover Burma and Indo-China, and between which flow the Mekong, the Salwin and the Irrawaddy. These heights are so steep, so densely wooded, and so well protected by an atrocious climate and a savage population, that even the undaunted energy of the Indian Geological Survey has made only partial progress among them.

Volcanic Disturbances in the East Indies.

Except in the Caucasus, the E. Alps, and N. Afghanistan, these epoch-making movements had not been characterised by great volcanic outbreaks; but we now come to a region where the latter more than make up for their deficiency elsewhere—to wit, Sumatra and Java, where several mountain ranges 10,000 to 11,000 feet high are, in the main, composed of vast outflows of lava and piles of ashes, the products of innumerable eruptions which once extended from end to end of those two long islands (Plate 93, B). What a spectacle for the gods it must have been to have stood, on some imaginary pinnacle well out in the Indian Ocean, and surveyed this smoking and burning chain, 1,700 miles long, with hundreds of craters black and forbidding by day, red as hell by night! Even to-day, there are in the two islands over fifty active volcanoes, ranging in height up to 12,000 feet; and these are but a remnant of the former activity. The line of smoking cones goes east beyond Java as far as Flores; at the other end it is continued through Barren Island into Burma and Yunnan.

In those days, the East Indies could not have been a particularly pleasant place in which to dwell. North of the islands just mentioned, Celebes, perhaps the most curiously outlined island in the world, rivalled Java in the number of its eruptions. This strange land forms a series of parallel north-and-south trending mountain ranges, which near the Equator have been abruptly deflected towards the east. The mountains are in some parts bordered by rift valleys, wherein lie lakes of extraordinary depth and brilliancy of colouring. The elevation of the island, beginning in the Miocene Age, was not completed until the Pliocene (187). Borneo also took part in the general upheaval, its central mountains being formed at about this time, with the same sequel of eruptions that the other islands exhibited. Finally, in New Guinea, we have a long range of mountains running east-west, with an extraordinarily steep drop on the south, bordered by foothills whose aspect suggests just about as much denudation as might have taken place since later Tertiary times. Very little is known of the geology of the island; but we should not be carrying analogy too far, perhaps, in tentatively assigning its uplift to the same age as those of its neighbours, especially as at least one of its great peaks (Mount Wilhelmina, 15,125 feet high) has its summit composed of Eocene limestone (188).

World-wide Nature of the Mountain-building Movements.

Thus, from end to end of the Old World, we have traced a line of heights that, in its early youth, and before the destructive fingers of frost and rain had made much progress, must have been a singularly impressive feature of the globe. Quite apart from its scenic aspect, its influence on the climate and the distribution of animals must have been enormous. After, and probably during its creation, the lands to the north of it became gradually colder and colder; and the palms and other tropical plants which had in Oligocene times flourished in Britain, migrated farther and ever farther to the south. We shall have more to say about this gradual refrigeration presently.

One might imagine that the disturbances already outlined were sufficient for any one age to assimilate; but no! They had their counterparts and reactions all over the globe: a sure indication, this, that the disturbances of the sub-surface terrestrial matter were connected by some easily responsive medium, such as a molten magma stretching uniformly beneath the Earth's crust.

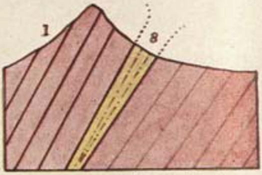
The Great Rift Valley.

From building up, we will glance awhile at sinking down, and consider Africa. On any good map of the physical geography of that continent, it will be seen that the lakes Nyassa, Tanganyika, Kivu, Albert, Rudolf and many others, lie in more or less elongated depressions of the surface. These, in their central and southern parts, run from north to south, somewhat *en échelon*, like the mountain lines of other regions. They vary enormously in their length and depth; but one long depression, known as the Great African Rift Valley, can be traced, with minor interruptions, all the way from the bank of the Zambesi River to beyond the Lake of Galilee; embracing, in one formidable line, Lakes Tanganyika, Nyasa, Kivu, the Albert and Albert Edward Nyanzas, the Semliki River and the base of the mysterious Mountains of the Moon (Ruwenzori); the lava-covered deserts of Somaliland, the bed of the Red Sea and the Gulf of Akaba, and finally, the line of the Jordan, the Dead Sea and the Sea of Tiberias. This great depression, though less talked of than the Himalaya, for example, is just as magnificent a natural feature of the Earth's surface; we must not always look upwards for the wonderful, for we can sometimes find it beneath our feet. Just consider, for a moment, merely a few of the depressions in the Great Rift Valley. It splits a volcano that is 12,000 feet high into two (189). Its bed, in the bottom of Tanganyika, is 4,188 feet below the water-level, or 1,628 feet below the sea, although it is many hundreds of miles inland. Near its other end, the surface of the Dead Sea and the Jordan are 1,300 feet below the level of the Mediterranean; and the depth of the Dead Sea adds another 1,300 feet to this. Between these two abysses we have that of the Red Sea, going down at least as far as 7,500 feet. And yet, excepting students, hardly any one has ever heard of this tremendous natural feature! It is interesting to observe that in the fresh waters of Lake Tanganyika, a number of marine animals, including jellyfish, were discovered a few years ago, of primitive types such as lived in the world ages since (190); exactly how they got there, and how they survived the change of habitat, is still a matter of controversy.

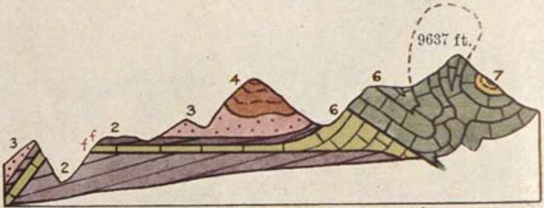
The eastern wall of the African Rift Valley is usually very abrupt and cliff-like; but on the west, where the geology is much more complicated, it is often ill defined. Its existence is the result of more than one dislocation of the crust, along a line of weakness which persisted certainly since Eocene times: and observations for gravity made in recent years in its bed

Pl. 94. **Igneous Scottish Mountains in Lorne, partly of Miocene Age (p. 242).** *S* 274.

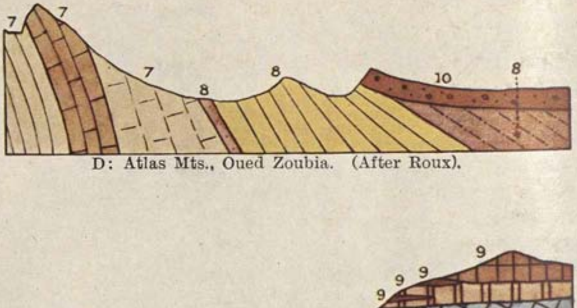
A: Wetterhorn (Alps), 12,166 ft. (after Bertrand & Golliez)



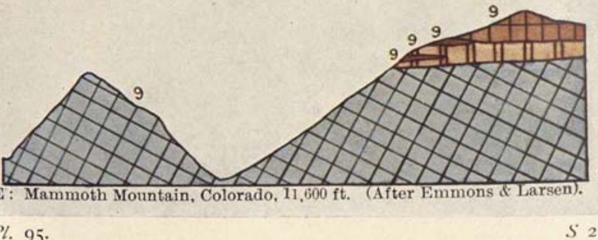
B: Silverhorn (N.Z. Alps), 5,686 ft. (after Park).



C: Pyrenees near Gavarnie (after Carez).



D: Atlas Mts., Oued Zoubia. (After Roux).



E: Mammoth Mountain, Colorado, 11,600 ft. (After Emmons & Larsen).

Pl. 95. *S* 275.

Sections through Miocene Mountains.

1. Gneiss & Schist. 2. Silurian. 3. Devonian. 4. Carboniferous. 5. Jurassic. 6. Cretaceous. 7. Eocene. 8. Miocene. 9. Miocene Lava. 10. Pleistocene. f.f. Faults.

indicate that here, as in the Ganges plain, there is by no means the stability which bespeaks terrestrial peace. Throughout the long time that has elapsed since its formation, one part or another has been the seat of tremendous volcanic activity; some of these volcanoes are erupting still, others, crumbling and vegetation-mantled, have long since blown out their fires. A very noteworthy result of the more recent eruptions is shown in Lake Kivu, which is held up on one side by a great mass of lava, and has had its drainage reversed in consequence (191).

Miocene Life near Victoria Nyanza.

During one of the general depressions in the early Miocene days, the Victoria Nyanza extended considerably farther to the east than at present; and in its bed many forms of life were buried, some of which have recently been exhumed. They show us that the country was peopled by a large number of animals—elephantine forms (Dinotherium, which had re-curved tusks), rhinoceroses, cats, rats, gigantic turtles, and crocodiles (192). At a later date the lake region was tilted up and buried beneath a deluge of black basalt (193).

Egypt.

In sympathy with these various disturbances, the region of the Lower Nile took a plunge beneath the sea during this age. The Mediterranean advanced at first to Cairo, and then as far as Ninia; only to slowly recede again. The present bed of the great river, so far as known, is of relatively recent date, and we shall refer to it again later.

New Zealand participated in these Movements.

Of the oceanic islands, New Zealand, that most troubled of volcanic regions, had of course a share in the upheavals of

Miocene times. The Southern Alps, a lofty and exceedingly wild and beautiful range, 450 miles long, and attaining, in Mount Cook, a maximum elevation of 12,400 feet, at this time received its principal uplift. These mountains, whose glaciers descend into the heart of a dense semi-tropical forest, within a few hundred feet of sea-level, and whose ruggedness has well-nigh made two separate worlds of the east and west sides of the Island, lie in what has been a zone of constant disturbance since times long prior to the Miocene. It will be remembered that in prior ages there was high land where the stormy Tasman Sea now heaves, and that in the Eocene the present line of the Southern Alps was defined. The whole region seems to have then undergone long-continued and vigorous erosion, due, perhaps, to a rainfall as abundant and destructive as that which so liberally planes away the surface at the present day; eventually being reduced to a general level, from which residual masses rose, castle-like, to a moderate elevation. Then came the early Miocene disturbances, with intense pressure directed from the south-east towards the north-west: long, strong, parallel folds in the rocks were initiated; and numerous over-thrusts of varying magnitude were developed. At the same time, or shortly afterwards, the old land to the west finally disappeared beneath the Tasman Sea, where it has remained ever since. The elevatory movements were again renewed under the mountain axis in Pliocene times (Plate 95, B); and there is ground for believing that further uplifts took place even subsequent to that, and that they have not yet ceased (194). Meantime, in North Island a second vast flood of lava and volcanic rubbish had overwhelmed much of the land; later on, it was followed by a third. This region seems, in fact, to have been longer in a continuous state of unrest than any other part of the world; and the great Tarawera eruption of 1886 shows how far from the end of the road of red ruin this island still is.

AUSTRALIA.

Australia did not participate, to any marked extent, in the more violent earth movements of the age. Being very largely a mass of extremely ancient rocks, it stood like a buttress in the midst of the storms, disdainful of their fury. But the earth demons gave it a shake or two, nevertheless. Thus, the country all around Lake Eyre, which had formerly been a large southward extension of the Gulf of Carpentaria, began to sink after the waters of that bay had withdrawn to the north. Lake Eyre and its satellite bodies of water were then the common meeting ground of rivers that flowed inwards towards the heart of the continent; but the advent of a hot continental climate, and the increasing desiccation, evaporated the lakes away into their present attenuated outlines, and created the sterility for which that part of the world is so notorious.

Beyond this basin, in the neighbourhood of Adelaide, a long series of severe earthquakes along narrowly defined lines gave rise to a rift valley, which includes Lake Torrens and Spencer Gulf. To the south-east, in Victoria, there were oscillations of a more regional extent between marine, lacustrine and freshwater conditions; and here, as the Miocene drew to its close, a spasm of eruptive activity broke out, depositing great sheets of basalt, which are sometimes 300 feet thick, upon the surface.

ELEVATION OF THE ANDES.

Coming next to America, let us first glance at the longest and perhaps also the greatest monument of Miocene times in the world—the Andes. We must endeavour to visualise the Andes as a great triangular highland or massif lying almost on the Equator, from which double chains of snowclad peaks stretch in imposing and solitary majesty north and south until the whole line spans 5,000 miles. It has been estimated that there is in the central massif itself enough material to raise the level of all South America by 378 feet (195); but this huge bulk of rock is not concentrated in a tableland alone. It occupies a high plateau, 12,000 to 15,000 feet above the sea. On its eastern border, a great range of little-known peaks, soaked in moisture and crowded with vegetation up to tree-line, abruptly fronts the plains and foothills of the Upper Amazon. On its western border, an equally high mass, largely composed of volcanoes both active and extinct, looks towards the Pacific over an arid, eye-aching yellow desert. In between these ranges lies a third. The plateau itself is, on the whole, bleak and forbidding; and yet it formed the cradle whence the Inca race passed to their conquests; and it still contains the monuments of their past civilisation, strangely combined with the dwellings of more modern seekers after gain, in Cuzco, La Paz and a few mining camps.

Both north and south of the central massif, the Andes lose gradually in elevation, although occasionally giants like Aconcagua and Chimborazo may be found in the midst of much smaller neighbours. But the abruptness of the chain does not lose by its loss in altitude; for whereas the higher peaks rise from a high plateau, the lower ones, such as Sarmiento, start almost from the level of the sea; and the eye may take in at a glance the magnificent spectacle of a precipitous slope 7,000 feet in height. South of Bolivia, the Andes narrow to a double chain, and for a long stretch in Chile they appear to be but a single line; but this is a geographical deception, there being an outer range (indicated by the long string of islands that border the coast) which has been partly submerged beneath the sea. The valley between these and the mainland now forms some of the deepest existing fjords. North of Bolivia, on the other hand, the massif stretches out numerous arms across

Ecuador and Colombia, which gradually decrease in height as they get nearer to the Caribbean Sea.

It is obvious that in this vast stretch of 5,000 miles the history of elevation has not everywhere been the same; and despite the efforts of various eminent men, the tangled story of the Andes has by no means been unravelled. But from sections made across the principal ranges, we are led to infer that they are to a great extent of Miocene Age, and in part even younger. The Western Cordillera of the Andes, if we exclude the more recent volcanic peaks which are its principal feature at present, is much the older of the two main chains; and prior to Miocene times the great plateau, up to and beyond the site of Lake Titicaca, was beneath the waves. On the east, where the Argentine and Patagonian plains now range, stretched a large lowland, probably far out into the Atlantic; but there were widespread oscillations of level, and at one time the sea washed as far west as the Cordillera itself. The lowland appears, in the main, to have been damp and well forested and grassed; and in it, at one time or other during the Miocene and Pliocene Ages, lived a vast range of mammals, largely peculiar to that one region, and most nearly allied to the contemporary fauna of Australasia: which seems to indicate at least a temporary land connection across the whole of the Southern Ocean. There were both flesh-eaters and plant-eaters, armadillos, marsupials, peculiar hoofed animals, monkeys, and a host of other forms. Many of these lived in that region whilst the Andes were actually in course of uplift; and they were probably quite unconscious of anything abnormal going on around them, so slowly did the changes operate.

The gathering storm broke, apparently, from the west. Slowly the rocks were pressed up into long, relatively simple folds, with very little mashing or overthrusting. Into the gaps created by their uplift huge masses of molten magma were pressed, rising up as great domes, and slowly solidifying only when they had attained an elevation of thousands of feet above the sea. One such crystalline "core" is at present exposed to view at 17,000 feet up; from which we must conclude that a very great thickness of matter has been stripped off the surface since it rose. Mr. J. A. Douglas, who has made several traverses of the central Andes in recent years, believes that this particular mass extends throughout the whole length of Peru, or 1,500 miles.

Volcanic Activity in the Andes.

The unusual strain on the Earth's crust set up by the extraordinary height to which the molten magma penetrated, opened a multitude of fissures, particularly on the western side of the Cordillera; and here the ejecta of unnumbered eruptions built up a great number of cones, some of them of extreme size and regularity. In one place or another, the activity of these volcanoes has continued right down to recent times: witness what an acute observer of men and nature has to say about it:

"From Guayaquil to Quito, across the Chimborazo pass, we ride in the heart of probably the most volcanic region of the world. Mother Earth, even in recent centuries, has been torn and twisted into the wildest forms. Beds, from 10 to 20 feet thick, of fine fragmentary rock are often exposed where the road cuts through a hill slope. I noticed a single fragment, weighing perhaps 40 tons, which must have been thrown from Cotopaxi, 20 miles distant. The highway has deep excavations, often showing successive layers of volcanic material. In one place is a top cap of earth 3 to 6 inches thick, then 12 to 36 inches of pumice from the size of a pea to that of a pigeon's egg, then 18 inches of earth, then 5 feet of pumice and ash, then about 5 feet of earth, and then down to a depth of 40 feet below the surface of the cutting an immense cap of ash and pebbles of pumice. All these beds vary in thickness according to the direction of the wind at the time of their deposit, which during the eruptions of Cotopaxi frequently blows with terrific violence. At some points the deposits are light, at others very heavy; and one may thus understand that Cotopaxi could form high hills by its periodic discharges into the vast valleys which it overlooks. . . . The tambo keeper at Machachi says that the last eruption (in 1878) buried the neighbouring country 3 feet in pumice. 'It was intensely dark from 9 a.m. to 11 p.m. Cattle, sheep, horses and birds died in great numbers.' " (196).

But if some of the Andean volcanoes are terrible by reason of their restless activity, others are not less so in their silent majesty. Such an one is the giant Misti (20,320 feet), which, rising in stately lines above the narrow streets of Arequipa, stands in regal solitude, a brooding menace to mankind.

Contemporaneously with the uplifts, thick masses of marine rocks were laid down against the Northern Andes: these are now exploited for petroleum.

ANDEAN EARTHQUAKES.

Volcanic manifestations are not the only indication of terrestrial instability in the Andes region. The frequent and exceptionally severe earthquakes to which the whole of the Pacific coast is subject speak even more eloquently of the unrest beneath the surface than do their fiery coadjutors. And almost as long as the human race shall endure, little else can be expected; for in this part of the globe we have in immediate juxtaposition some of the greatest heights and deepest hollows of the Earth's surface. The Andes rise to nearly 20,000 feet, the sea bottom just off-shore descends to 28,000 feet; giving over 9 miles of vertical difference—a gradient so steep that further large natural changes would seem necessary before the internal sores can heal.

CENTRAL AMERICA; WEST INDIES.

Central America also participated in the Miocene earth movements, and at the end of the age, Nicaragua became the scene of violent volcanic outbursts (197). During the Miocene, the land connection was broken; but was re-established by mountains trending E.–W., *i.e.* at right angles to the Cordilleras.

In the West Indies, the Caribbean Sea foundered at this time; and on its periphery volcanoes built up the substratum of the Windward Islands.

Great Movements on the Pacific Coast of North America.

Finally, we reach the Pacific coast of the United States and Canada. Here we find the same great zone of longitudinal weakness, extending even to Alaska, but not attended with the same violence or magnitude as the South American coast attests. In both Miocene and Pliocene times, much of the States of Washington, Oregon and California oscillated between marine and terrestrial conditions. The former age was characterised by the presence, both in marine and fresh waters, of countless myriads of diatoms and foraminifers; a fact of immense importance to human beings. These diatoms are microscopic plants, possessing a jelly-like substance, encased in a cover of hard silica; the cover, or skeleton, is often of exquisite beauty and delicacy, designed in nearly every possible symmetrical figure: triangles, spindles, ellipses, squares, stars and circles. Yet it is difficult to find two of a kind that are identical. In some of the old Miocene lake basins of the Western States the skeletons accumulated to such an extent as to form beds of rock several feet thick; this is much used in commerce, for polishing purposes principally. Similar diatomaceous earth is found at Bilin, in Bohemia; and there some 40 millions of diatoms may be found in one cubic inch of earth! But the great importance of the diatoms lies in their substance being more or less oily, so that when they died small globules of oil were extracted from their tiny bodies in order that we moderns might drive Ford cars! The exceedingly valuable petroleum fields of California are of Miocene and Pliocene age; the oil being found in sands which were laid down along shallow shores in relatively deep and narrow troughs. Countless dollars have been expended in exploiting this oil, and untold numbers of barrels have been extracted; and all this is due to a microscopic plant having lived there millions of years ago. Truly is the great concealed within the little! Another, and less creditable use of diatoms has been made in the manufacture of dynamite, which is nothing but nitroglycerine absorbed into the cavities of diatomaceous earth.

In the middle of the Miocene, the Pacific coast of the States was subjected to strong Earth movements; the beds were folded, and a large area of what is at present ocean floor became land. In Vancouver Island, and in the interior of the mainland, vulcanism broke out; and it has continued, with intermissions, right down to recent prehistoric times. At this time the great range of the Cascades, which is to-day one of the outstanding features of that region, had no existence. It was forced up by further movements at the close of Pliocene time; and is thus one of the youngest mountain ranges on the globe. The numerous stately cones that line its crest, Mounts Rainier (14,444 feet; Plate 92), Adams, Baker, etc., were built up by eruptions which followed the elevation of the mountains, some half a million years ago, and which have not yet ceased. Here, again, double proofs of crustal instability are shown by earthquake and volcano; as witness the disaster at San Francisco in 1906, when five hundred people lost their lives, and the still more recent outburst of Lassen Peak in 1912–15.

North American Lava Flows.

Of the Mio-Pliocene lava flows of the western States, the two most celebrated are the Columbia Lava Plains and the Snake River Plains. The former outpourings rivalled in thickness and extent those of the Deccan in Cretaceous times. They cover an area of 200,000 square miles; the average thickness of the flows is 50 to 80 feet; and individual flows have been traced for distances up to 100 miles. This terrible devastation, by the by, ushered in the age. It was followed, considerably later, by the much smaller but still very extensive eruptions, similar in nature, which border Snake River. The latter have continued, with breaks, right down to historic times. The great bulk of the lava is believed to have welled up quietly through fissures; it probably travelled rapidly, and it must have wiped out all but the swiftest of living things that chanced to be in its path.

The lava in the Snake River district has given rise to a very peculiar type of scenery, which cannot be better described than in the words of Sir Archibald Geikie:

"We rode for hours by the side of that apparently boundless plain. Here and there a trachytic (volcanic) spur projected from the hills, succeeded now and then by a valley up which the black flood of lava would stretch away into the high ground. It was as if the great plain had been filled with molten rock, which had kept its level, and wound in and out along bays and promontories of the mountain slopes as a sheet of water would have done" (198).

But though, prior to its serious decomposition, the lava forms a barren, hard and jagged surface, once it is worn down into soil it makes exceedingly rich land. Thus it chances that many of the splendid wheat fields of Oregon and Washington are due to the timely disintegration of the products of these ancient volcanoes.

Gradual Recession of the Sea.

In the southern United States, the embayment of the Mississippi slowly became smaller and shallower as the sea withdrew to the south, until by the close of Pliocene times the marine waters occupied approximately the position in the Gulf of Mexico which they do at present. But Florida was still going up and down, cork-like, and that most charming of States is still half drowned. Along the Atlantic border, the long succession of oscillations that had lasted since Cretaceous times went on without intermission. In Maryland, it has left us a couple of noteworthy relics of these times, in a bed of rock, 20 feet thick, composed in the main of minute diatoms, and in part skeletons of several kinds of whale.

BRITAIN IN THE MIOCENE AGE.

After this rapid review of the great whirl and turmoil of those ages, it seems a little absurd to refer to England, where there appears no trace of such events. Yet the Chalk hills of the southern coast, and of the Isle of Wight, are a minor manifestation of the same great forces which pushed up the Alps. In cliff sections in the Isle of Wight, the summer visitor may see for himself, as clearly as if it were traced on a blackboard, the great curve which the chalk (almost vertical) and the superposed rocks of Eocene age make (Plate 88, A). Throughout most of the Miocene, our country was dry land, and there are no deposits whatever by which we may distinctly recognise its presence; but it is not unlikely that the final lava flows of the western Highlands of Scotland took place at the very beginning of the age. That the land was warm, well wooded, and peopled by many kinds of animals, we may rest assured, from remains which have been found on the continent.

But although there is very little trace of it, south-eastern Britain was deeply, though only temporarily, submerged in Pliocene times, probably to some 800 feet. Fragmentary traces of this submergence are afforded by rocks to be seen at Lenham, in Kent, and far west along the North Downs. More considerable accumulations of marine shells, sand and mud took place in East Anglia. They all indicate that the extreme heat of Oligocene times had completely passed away; and the uppermost of them, to which we will refer in the next chapter, gives us the first indications of the Ice Age. The end of the Pliocene all over the world cannot have been much more than half a million years ago, and was probably less. It saw the continents almost in their present form; but the relief of the land was rather different.

Climate of the Age.

The early part of the Miocene was marked, in Europe and elsewhere, by a warm, uniform climate; a considerable modification from the tropical Oligocene, yet considerably warmer than the same latitudes are to-day. On the Atlantic coast of North America, on the contrary, it was cooler; and the coral growths of the warm seas withdrew far to the south. As the age advanced, a progressive cooling of the temperate and boreal regions took place; and this went on, throughout the Pliocene, until it became so cold that permanent snow could lie in the neighbourhood of London, and what is known as the Ice Age began.

The flora, of course, followed the climate. As the heat disappeared from our latitudes, so did the palms, screw pines and their kind; and more temperate species, including a great number of grasses and deciduous trees, took possession of the land, forming vast natural parks wherein deer in the north and antelope in the south favourably develop.

Animal Remains.

Animal remains of the age have been preserved in great numbers, especially in the deposits of the Austrian Lake Basin, the Himalayan foothills, Egypt, Greece, North America and the plains of Patagonia. They show a great assemblage of animals, including a number of modern genera, besides various bizarre creatures whose appearance heralded their extinction. Elephantine creatures became very abundant (Plate 98): the giant Mastodon and the peculiar aquatic form Dinotherium were the dominant types. There were many kinds of rhinoceros, and numerous pigs, some of very powerful and savage appearance. Horses continued their steady evolution towards *Equus caballus*. The giant hippo wallowed in the mire. The open grassy places served as a playground for great herds of deer and antelopes; while in their vicinity, as well as in the dark confines of the jungle, lurked beasts of prey—hyænas and the wicked-looking sabre-toothed tiger. The earliest bruin stole fruit from the trees. In forest glades beavers built their dams; whilst overhead in the branches were clusters of monkeys. The air was peopled by most of the birds that exist to-day; the water, by most of the fish. Snakes, lizards, toads and frogs were plentiful by the side of the streams. It was in all respects, save one, a fully peopled world—there were no men. Persistent attempts have been made for many years to take our ancestry back to Pliocene times, but without a shred of evidence. So far as known, the advent of man dates from some time within the Ice Age.

Which takes us into another, and perhaps the most interesting chapter of the story.

CHAPTER XII.

The Ice Age (*Pleistocene*).

Glacial Drift.

The records which are contained in the last sediments laid down during Pliocene times brings us to the end of the Earth's history, as it was understood three-fourths of a century ago. Above these bedded rocks, and mainly in the northern hemisphere, lies a covering, thin and patchy for the most part, of clay, gravel and sand, in the midst of which are to be found numerous large boulders, sometimes as big as a house (Plate 99). The clay itself contains numbers of smaller boulders, down to the merest pebble; the sand and gravel are rudely bedded, and often conform more or less definitely to certain levels above the sea in each locality. Many of the stones bear grooves and scratches, and are polished so well that the rainstorms of hundreds of years will not remove the marks. Long ago, in the days of geological ignorance, it was believed that all this thin covering represented the effect of some great deluge; for no ordinary stream or torrent could move the huge boulders that lie perched promiscuously over the landscape. The impossibility of such a thing soon became evident, however; and it was then assumed that all the land had been submerged, and the materials transported to their present sites by floating ice. But the unassorted nature of the rocks, and the enormous differences of level at which they were found, weighed against such an hypothesis; besides, it was observed that the solid rock had been grooved and polished in precisely the same way as the travelled stones. Close examination of the facts over limited areas led at length in the direction of truth. It was noted that the grooves, scratches, or striæ, bore in certain definite directions, which, when mapped, usually led back to some high area from which they radiated outwards; as if an ice cap had laid thereon, and expanded by the force of gravity down into the valleys. Associations, both local and national, were formed for the purpose of studying the travelled blocks; these blocks, because of their seemingly errant distribution, early became known as "erratics," a name which has clung to them ever since, although at present hardly applicable. It was found that special and easily distinguished rocks, especially those of a crystalline nature, could be traced in long lines, sometimes for hundreds of miles, until at last their source was discovered in some worn peak far from their present situation. The sticky clay, known in Scotland as "till," in which the smaller stones are embedded, was shown to be the mud deposited by glaciers of regional extent. The ridges, hill-like in outline, ill-drained and with many curious hollows or *kettle-holes*, which marked the limits, or lay across the surface, of the till, were found to be identical in all respects with the rubbish heaps or moraines of present-day glaciers. The smaller stretches of neatly laminated clay, bounded by such ridges, were deduced to be the deposits of glacial lakes. Finally, the sand and gravel bore so close a resemblance to what would be spread out from the front of a melting ice sheet, that it was at once identified as glacial outwash. Thus, everything conspired to prove that this insignificant mass of stones and mud represents a striking incident in Earth history; and to-day, most geologists are agreed as to the main outlines of this incident, though differing, as experts will, about the details.

Slow Advent of the Ice Age.

It is quite certain that the Ice Age was a long time coming. It did not spring on the world in a moment. The gradual refrigeration of the northern hemisphere throughout Pliocene and even during later Miocene times; the growth of more and more temperate plants in high latitudes; and the slow southward spread of cold-water-loving molluscs: all point to the same conclusion. At the close of the Pliocene, the Earth's geography, as already stated, was essentially what it is now.

It has been postulated that the north of Canada, and the larger part of New England as well, were very much higher than now; but a recent (unpublished) study has convinced me that they were not higher by more than 1,000 feet or so, and could not have affected the climate greatly. When Pliocene time ended, England was coldly temperate, and was allied, where the Straits of Dover now run, to the Continent. Across this neck of land Continental animals passed; and in the early Pleistocene deposits of East Anglia have been found bones of cave bear, horse, rhinoceros, deer, elephants, cattle, hippopotamus, and others. Leaves of trees such as exist here to-day were also found. These deposits overlie the Norwich Crag, a shelly sand containing 33% of Arctic species; and I believe that Scandinavia had already been once overwhelmed by ice before the Cromer animals lived. The evidence of this early glaciation is clear, but it cannot be given in this book. After the mild or *interglacial* Cromer time, the chill arms of winter took possession of our land. Willows and Arctic birches replaced the beech, the walnut and the elm. Arctic shells were in the waters, and the little Arctic fox had his covert on the land. The snowfall, which must for some time have been a regular feature of the winter, now extended into the summer also; with the result that more accumulated than the sun could melt. In the higher lands, small glaciers formed in sheltered places. Growing outwards by the annual accumulation of snow, and coalescing with other small glaciers, these bodies of ice soon became formidable masses; and the continual refrigeration of the atmosphere, combined with the equally regular supply of moisture, adding to their load, gave them motion, so that they overflowed down into the valleys and the plains. One by one the animals fled away; even the hardy mammoth betook himself to some more favoured clime. But the vegetation, powerless to save itself, shrivelled and bare, either perished of cold or was overwhelmed by the ice; and the face of the land became a barren desert of white, given over to what seemed eternal winter.

How long this state of things lasted, no one can say; we can only measure the duration of the glaciers and ice caps by the debris they have left behind them; and of the first great ice invasion, there are universally only the most meagre traces; and, as we have said already, it barely touched Britain, though glaciers probably crossed the North Sea to Aberdeen.

Melting of the Ice Sheets.

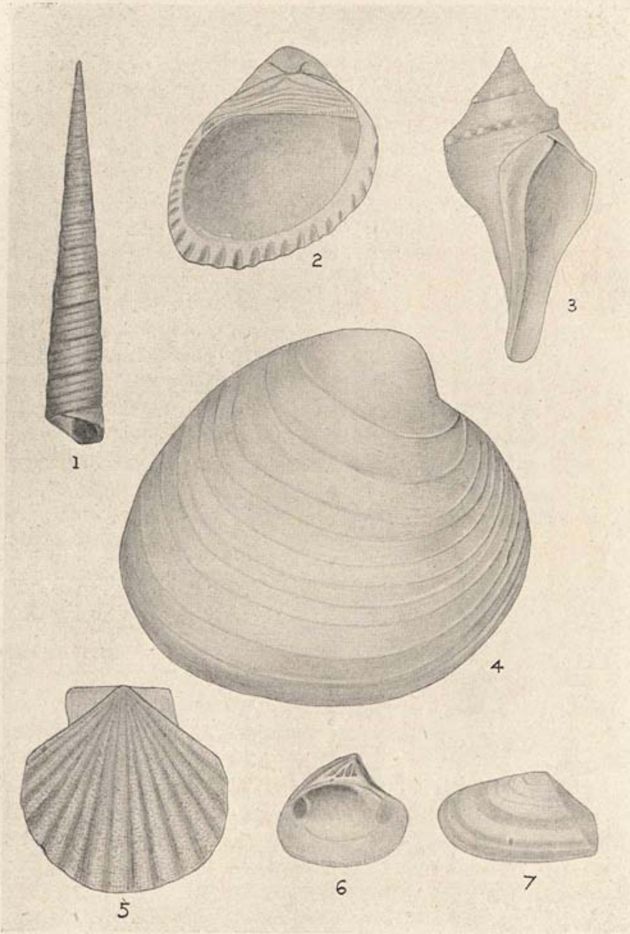
Eventually, however, a change set in. It is probable that the extreme cold and rarity of the atmosphere did not favour precipitation, but the contrary; thus, the sources of supply being dried up, the ice sheets gradually withered away. The sun, too, acquired more real heat; and the icy nightmare vanished into its northern fastnesses. But only for a time. A repetition of the refrigerating process brought it back again; and this continued until, in many parts of the world, no less than four cold and three warm stages occurred. There is a great deal of evidence, also, to indicate that we are even now only in an intermediate condition between two ice invasions: an *interglacial stage*, as it is termed.

THE CAUSE OF THE ICE AGE.

So much for the Ice Age in general. We will examine it in some little detail presently; but first, we must devote a few words to its cause.

The cause of the Ice Age has never been and is not yet understood. Some very ingenious theories have been built up to explain it; but they all fail in one essential point or another. That which long found most favour was the mathematical explanation of Croll. Now, every one knows that the Earth spins on its axis at an inclination to its orbit of 23½ degrees. Dr. Croll assumed that the Earth did not always spin constantly at the same angle; but that the position of its axis slowly altered, so changing the points which received least light and heat from the sun. There is other evidence to show that the position of the Earth's axis *may* alter; but this ingenious theory cannot in any manner explain the Ice Age, because, not only has there been a series of ice invasions within a very short time, geologically speaking, but because the theory implies a constant succession of Ice Ages, first in one hemisphere, and then in the other; which certainly has not been the case. A further and completely fatal objection is that during the Ice Age the temperature of the whole globe was lowered; for the glaciers descended far lower in tropical regions than they do at present; and in the South Temperate Zone, the mountains show without exception a similar state of affairs. Finally, it is practically certain that Antarctica was as ice-bound as the Northern Hemisphere, at a time when, according to the theory, it ought to have been enjoying a genial climate (199).

Other theories claim that most of the northern hemisphere was much higher than at present, so that a very slight lowering of the temperature would enable snowfields to form; but apart



Pl. 96. *T* 292.

Miocene Shells. 1. Turritella; 2, Arca; 3. Fulgur; 4, Venus; 5, Pecten 6, Astarte; 7, Tellina.

Pl. 97. *U* 293.

Map of the Ice Age in North America. (p. 294).

from the deeply submerged gorge of the Hudson River (200), and the inconclusive evidence derived from Baffinland (201), Ellesmere Land (202), and the adjacent islands, there is no support for these theories in fact; besides, all such elevations, even if they really existed, were local; whereas the glacial phenomena are world-wide.

A third group of theories may be said to deal almost solely with diminution and increase of the Sun's heat. Changes of climate over comparatively short periods of time, such as can be measured in years, are a well-attested fact; but the length of time to which they may be extended is another question. Some people believe in variations in the emission of carbon dioxide from the ocean, a process that is intimately connected with the height of the land above the sea. Sun-spots have been dragged in, to make our darkness deeper. A more illuminating suggestion is, that during excessive vulcanism, the transmission of the hot rays of the Sun to the Earth may have been interfered with; and in a very limited way, this is true; but it cannot, of course, satisfactorily account for a chilliness which endured many thousands of years. Finally, we have already seen traces of considerable glacial episodes during earlier ages, *e.g.* the Permian and the Pre-Cambrian (256).

My own belief is that the phenomenon is mainly, if not solely, due to variations in the gases comprising the outer layers of the Sun, *i.e.* the intensely hot hydrogen and the less intensely hot calcium vapours or flocculi.

The Ice Age in North America.

In considering the Ice Age in detail, it is best to glance at each great area separately; for in no two of them was the succession of events quite the same. Firstly, then, we will treat of North America, where these deposits are exhibited in great perfection.

There were three main gathering grounds for the vast masses of ice that overwhelmed most of North America: in Labrador, in the trackless wastes to the west of Hudson Bay, and in the Cordillera (Plate 97). In addition to these, every sheltered slope in any region of high relief must have nourished small local glaciers; but the main streams came from the three areas just indicated, and overwhelmed in their advance all traces of subsidiary ice action. We must imagine, then, that towards the close of Pliocene time, the climate of the whole region north of the International Boundary, which had long been steadily growing colder, became so chill and cheerless that most of the precipitation was in the form of snow, which the Sun had not strength enough to melt. Accumulating, layer above layer, to a vast thickness, it finally formed a mass resembling in every detail the ice cap existing to-day over Greenland, or the similar but much larger one which buries Antarctica. It advanced southwards through the pressure caused by fresh accumulations of snow at its apex; and north of its gathering grounds it advanced northwards as well. Creeping down valleys and over hills, with a contemptuous disregard for the topography, it involved first the bulk of Canada and then much of the Middle Western States, as far south as Kansas. The final line of its advance, which in this first invasion is only imperfectly known, is shown approximately on the map.

Ice-Age Mammals.

At this time, the great plains region in the centre of the continent was the home of many kinds of mammals—various horses, camels, sabre-toothed tigers, goats, dogs, bears, rats, giant beavers all abounded; while the powerful mammoth (Plate 106) and other elephantine creatures roamed far and wide. On the approach of the ice, one after another fled south, or perished. The vegetation, rooted to the soil, withered and died. The ground, reduced to a semi-barren grass-covered waste, became frozen hard. Finally, the ice, moving perhaps only a few feet per year, perhaps many hundreds of feet, according to the local topography, overwhelmed everything. There were temporary recessions, during which areas that had once been covered became clear again ; then further advances, until the limit of advance had been reached.

THE NEBRASKAN ICE SHEET.

Most of this ice probably came from the centre west of Hudson Bay, which is known, from the rocks which are there predominant, as the Keewatin centre. How long it lasted we cannot say. All that is certain is, that it retired as gradually as it had come ; and so gave rise to the first interglacial stage. This ice invasion is known as the *Nebraskan*, from the typical exposures of its debris in that State.

THE AFTONIAN INTERGLACIAL STAGE.

The immense bodies of water which were released as the result of the ice melting, created large flood plains of gravel and sand, and definite watercourses were channelled out of the thick sheet of clay that had been left by the ice. After a time, the amelioration still continuing, hardy weeds got a foothold on the barren ground ; still later, higher types of vegetation crept north ; and in due course, the animal life followed it, and the land was again almost as it had been before the invasion. Almost, but not quite ; for old drainage lines had been blocked up, and new ones made ; and in the hollows in the ground moraine left by the ice, many lakes, the counterparts of those which still beautify Indiana and Wisconsin, had a short existence. Soils, sometimes many feet thick, were slowly evolved from the crumbling surface. Great plant-loving animals, principally extinct sloths as large as an elephant (Plate 100), rooted up small trees, or lived on the succulent grasses that filled the meadows and bordered the lakes.

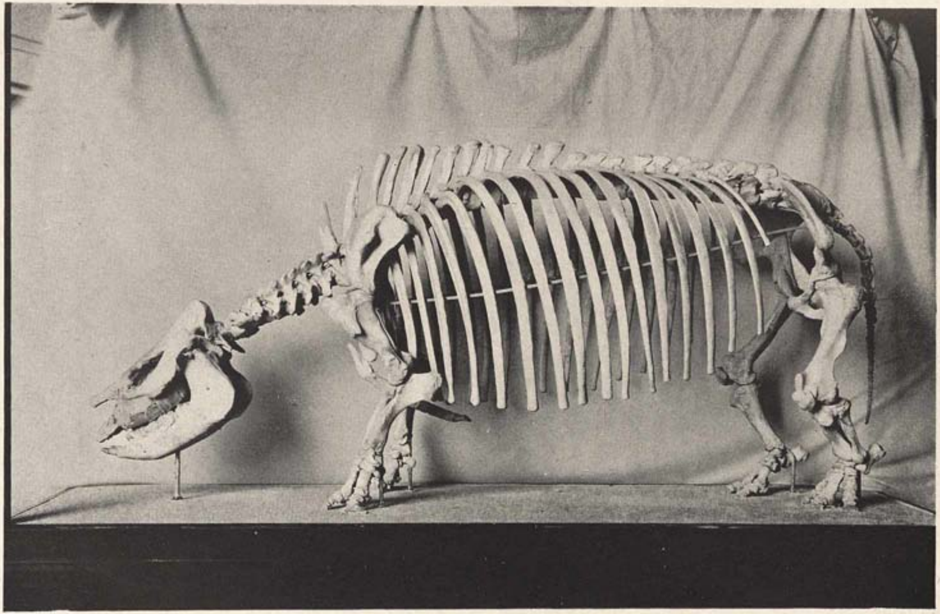
Invasion of the Kansan Ice Sheet.

And then the invisible terror manifested itself again. The rain changed once more to sleet, the sleet to snow, and the snow to ice. The animals once more hurried south, some of them never to return. The plants once more perished. Eternal winter, as it seemed, once more reigned supreme. This time the ice covered a much greater area—the maximum, perhaps, which it ever attained. The invasion is known as the *Kansan*; the intervening mild period between it and the Nebraskan ice sheet, as the *Aftonian*.

The Kansan ice sheet ploughed up and obscured much of its predecessor's handiwork, besides removing great quantities of soil and subsoil from other areas. As is shown by the great thickness of the moraine that it left behind, it endured for many hundreds and probably many thousands of years.

The Yarmouth Interglacial Stage.

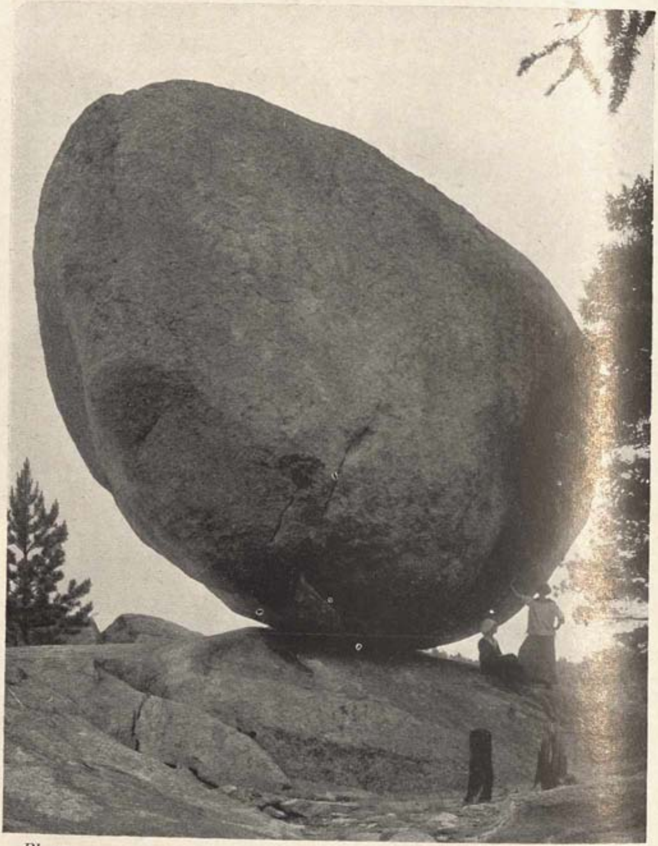
Once again the ice withdrew, giving place to the Yarmouth interglacial stage. The withdrawal was certainly as complete as the first had been, and probably the interval between this and the next ice sheet was exceedingly long. For the surface of the Kansan moraines, or "drift," was leached by long exposure to the air; soils were developed upon it, and a miniature topography of hill and dale was created out of it, ere once more the cold grip of the ice took possession of the land. In this interval, the animals and plants again moved north; among others, remains of shrews, bats, skunks, weasels, wolves, foxes, black bears, lynxes, beavers, deer,



Pl. 98. *U* 296

Teleoceras.

An extinct plant-eating Miocene mammal (p. 287).



Pl. 99. *U* 297.

Balance Rock, Platte Canyon, U.S.A.

A relic of the Ice Age (p. 288).

Photo. Wisirall Bros., Denver.

bison, musk oxen, extinct pigs, extinct sloths, and armadilloes (Plates 100, 103), and two or three kinds of elephant, besides the giant mastodon, have been found (203).

The Illinoian and Iowan Ice.

The next invasion came more from the Labrador centre, and is known as the *Illinoian*, the drift from which is best seen in Illinois. On the recession of this, there was another inter-glacial stage, the *Sangamon*. Forty per cent. of the fifty species of mammals which are known to have dwelt in central North America at this time are extinct (204). The mastodon, the mammoth, tapirs and bison still persisted; one after another, all have since died away, except the last, which is preserved as an everlasting monument to human folly.

It is at about this time that we first find evidence of the loess: a wind-driven dust which was left on the flood plains of the rivers formed by the melting ice, and which was blown far and wide about the basins of the Mississippi and its tributaries.

As I believe, contemporaneously with the Illinoian ice, an advance occurred from the Keewatin centre. A mass of drift of varying thickness was laid down, largely on top of the Kansan drift, but in such a manner that its present boundaries are very obscure, except in Iowa and Minnesota. A peculiarity of this invasion is, that it consisted in great part in the transport of boulders from the far north, sometimes for several hundreds of miles; blocks up to 50 feet by 40 feet by at least 11½ feet now overspread the country (205), as if some giant's hand had scattered lumps of sugar across his earthy table-top.

Desert Conditions of the Loess.

The recession of the Iowan ice was followed by semi-desert conditions which long endured. The sun acquired considerably more heat than at present exists in those altitudes; and in the neighbourhood of Ottawa and Toronto, plants grew which do not now flourish farther north than the south-central States. In some areas, there were, apparently, wide flood plains, deeply covered with rock flour derived from the melting ice. This dust, which has a peculiar cohesiveness, was picked up by the wind and spread, layer above layer, over the upper Mississippi region, until it attained considerable thicknesses—in one case 100 feet (206). This is the celebrated *loess*, a deposit the origin of which has given rise to some of the most acute geological controversies. Originally studied on the Rhine, it has since been recognised in many parts of the world, and always in areas in which (or bordering upon others in which) ice action has taken place in the recent past. It varies in colour, as a rule, from grey to drab, and stands up in vertical walls, yet is as soft as sand. Its grains are of the finest, like silt—the great bulk of them are under $\frac{1}{5000}$ of an inch thick (207). At all levels in it are to be found occasionally the delicate shells of land snails, which lived and died on its surface, ere the wind, transporting fresh clouds of dust thither, provided them with this unique mausoleum. The thicknesses to which the loess attained are truly astonishing; for in China and Mongolia they are not less than 1,500 to 2,000 feet; and there they have completely altered the aspect of the country, notably near the great bend of the Yellow River.

The Last Ice Sheets, the Wisconsin.

Following on the loess deposition came the final ice invasion, the Wisconsin, in two great advances, with many minor advances and retreats (208). In this case, as probably in the earlier ones also, the ice moved both north and south; for it carried boulders of Keewatin rock into the Arctic Ocean, and these were transported alongshore by floating bergs as far as to Alaska (209). Thus it is evidently wrong to regard any of the ice invasions as an "ice cap"; the "cap" only fitted part of the land, it did not necessarily, or even probably, cover all the Arctic regions. On the recession of the Wisconsin ice, the country gradually took on its present semblance; and the horses, tapirs, camels and sloths had gone from this land for good, while the elephants and mastodons gradually followed suit.

Post-glacial Lakes.

Now, as can be seen by any relief map, the heights and hollows of this part of the globe are not very pronounced. In pre-glacial times (certainly in pre-Wisconsin times), much of the drainage was to the north and north-east. When the ice covered all the region, there was of course no drainage, except from the ice-front; but as the ice retired, a very peculiar and complicated series of lakes came into being, the history of which has been worked out in great detail, by the numerous shorelines and beaches they have left behind them (210). The melting of the ice formed great accumulations of water, which was ponded up until it reached some pass or other, usually to the south, through which it could escape; and as the ice retired, this level grew lower on the whole, opening new outlets for the temporary lakes, and frequently reversing the direction of the drainage. All these fluctuations took several thousands of years; but the duration of any lake was short—probably only a few hundred years at the most. At one time, the Great Lakes were represented by an attenuated strip of water at the southern end of Lake Michigan; at another, they possessed a far larger area than at present; eventually, they gradually took up their present sites; and there they now are, the relics of the last Ice Age. One very striking testimony to the truth of all this is furnished by the gorge of Niagara, which undergoes various contractions and expansions, each the result of a time when little or much water was passing through. Another very remarkable fact in connection with these old lakes is the tilting of their shore-lines upwards as one goes north, this indicating beyond controversy that there has been a subsequent elevation of the land.

Glacial Lake Agassiz.

We cannot leave this part of our subject without at least a passing reference to a great lake which during this time filled the Red River basin, in Minnesota and Manitoba—to wit, Lake Agassiz. This was a vast sheet of water, at one time covering over 100,000 square miles of land, to a depth in places of 600 to 700 feet. Over the site of Winnipeg it was 550 feet deep. It was due to exactly the same cause as the other great lakes; its shrunken remnants are now to be found in Lakes Winnipeg and Winnipegosis. At first, it was a mighty feeder of the Mississippi; its outlet to the south being 1½ miles wide, and anything up to 125 feet deep (211). Later, the drainage veered round to the north and north-east; the last remnants of its shrunken glory now find their way by devious channels into Hudson Bay.

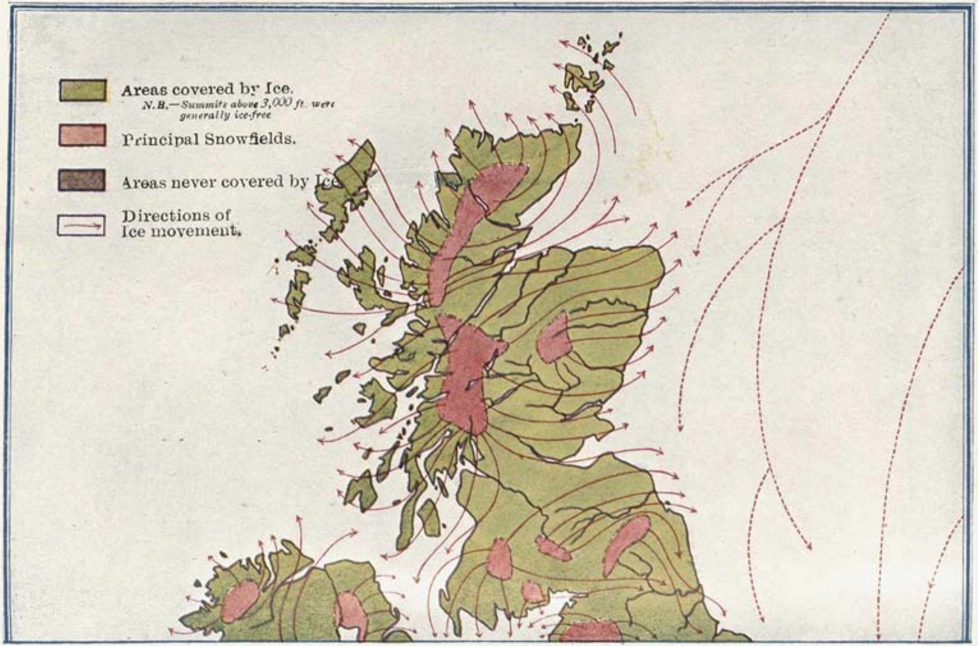
More than One Ice Invasion in Other Parts of America.

While the same great succession of advances and retirements of the ice has not been observed in other parts of North America, fragments of them, very suggestive in character, testify to the general course of events. Thus, in Long Island, four distinct glacial epochs with intervening periods of de-glaciation have left their record; and two of them have over-spread the site of New York (212). The farther north one

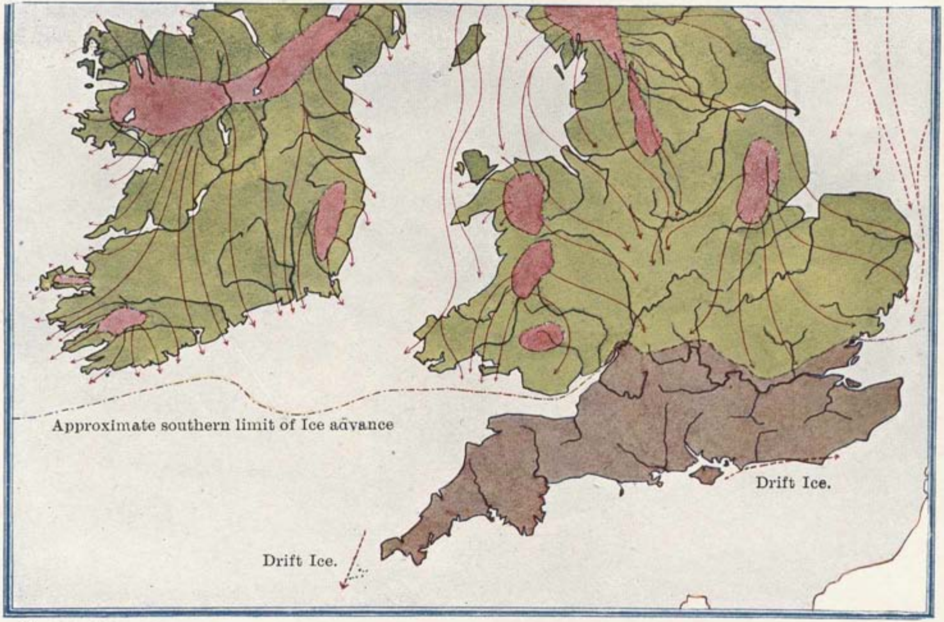
Pl. 100. *U* 300.

Megatherium.

A gigantic ground-sloth of the Ice Age; it was 18ft. 0in. high, and frequented the Argentine (p 297).

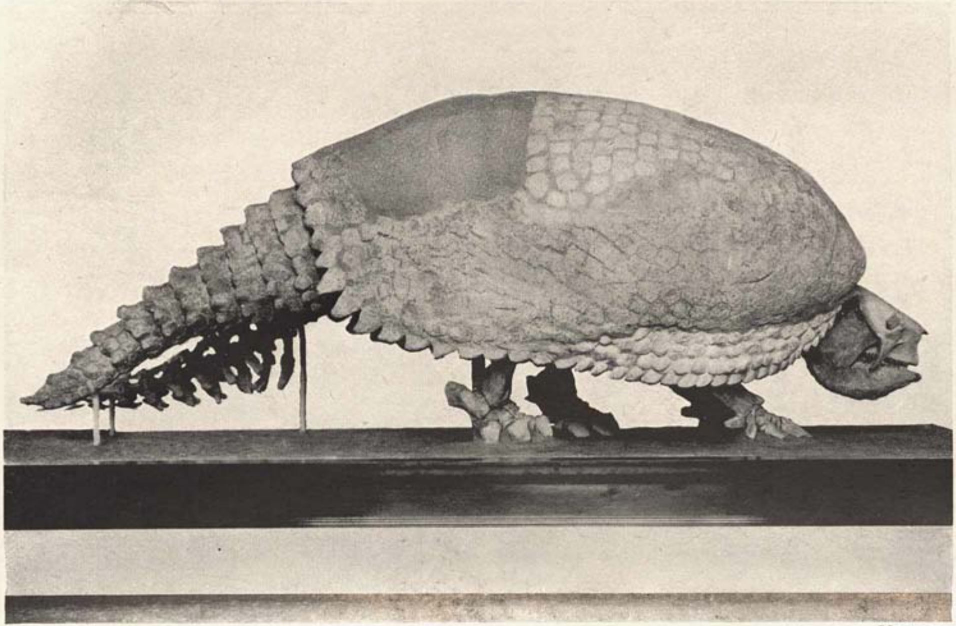


Areas covered by Ice.
N.B.—Summits above 3,000 ft. were generally ice-free
Principal Snowfields.
Areas never covered by Ice
Directions of Ice movement.



Pls. 101-102.

Map of the Ice Age in the United Kingdom and Ireland.



Pl. 103. *U* 301.

Glyptotherium.

A South American Armadillo, 10 feet to 12 feet long, which lived in the same glades as the great Megatherium (Pl. 100).

goes, the more difficult is it to distinguish the various glacial stages from one another; but even in Labrador there are at least two clearly distinguishable ones. In the Cordillera, where the ice was in places over 6,000 feet thick (213), two distinct glaciations occurred, and possibly a third. In Alaska, also, two have been recognised. In Utah, ice caps twice covered the local mountains; the Wasatch and Uinta Mts. nourishing dozens of small glaciers during this age (214). The San Juan Mts. had three glaciations; and the ice even overshadowed the plain where Los Angeles now stands.

Length of the Ice Age.

On account of its completeness there, as well as the wide distribution of its deposits, the Ice Age in North America furnishes us with a unique opportunity of gleaning some idea —albeit a hazy and approximate one—of the length of time which has elapsed since the commencement of glacial conditions. This is a point of very great interest, when we remember that it is only during the Ice Age that we first meet with undoubted traces of man. The estimate is arrived at by comparing the extent, thickness, degree of weathering and denudation, etc., which the deposits of each successive glacial advance exhibit, with the corresponding amount of change in post-glacial times; and as the latter is definitely known within a margin of a few thousands of years, the only differences are those which various observers place upon the same set of phenomena. On this basis, the generally accepted duration of Pleistocene time is some 300,000 to 400,000 years, of which more than half was probably consumed in the long interglacial intervals. Of the 20,000 years or so which make up post-glacial times, we will speak more fully below. Thus, somewhere about 150,000 years was in all likelihood the combined duration of the various ice invasions; and although this may seem stupendous, when reckoned in terms of a human life, yet it is a mere trifle by the side of the ages which have gone before. That it is at least of the correct order of magnitude, seems indicated by the following facts.

Rate of Ice Accumulation.

In North-West Antarctica, in 1902–3, Dr. Otto Nordenskiold made a special study of the rate of accumulation of ice, on a spot which was carefully selected 350 feet above the sea. The rate of accumulation, which in the winter was nil, varied during the spring and summer months; for the whole year it was between 6 and 7 inches (215). These observations, however, extended over less than two years. An old depôt laid by Captain Scott near the western edge of the Great Barrier Ice on his first expedition, travelled during the next six years at the average rate of 500 yards per annum, and a thickness averaging about 1 foot of consolidated snow per annum had formed upon it (216). Taking this figure of 1 foot per annum as more nearly applying, it would require 3,000 to 6,000 years for sufficient ice to form in any one locality, before it began its errant wanderings.

Erratic Blocks, or Boulders.

Again, great numbers of erratic blocks, both in North America and elsewhere, have travelled vast distances from their points of dislodgment—in many cases not less than 200 miles. They were borne to their present situations by the ice, and have not infrequently been built up by it into huge terminal moraines or rubbish heaps, 100 to 300 feet high, anything up to half a mile thick, and several miles in length. Now, at the rate of movement observed in the case of Scott's depôt (which is certainly much greater than would apply in the case of glacier ice travelling over a rough land surface instead of over a level sea) not less than 700 years would be needed before a single one of these stones could reach its destination. Something nearer the probable actual rate of motion of the ice, though still too rapid, is afforded by the movements of modern glaciers of the Alpine type having a low angle of fall. For example, in the Canadian Cordillera, observations extending over twelve years showed, in the case of three great glaciers, an average daily motion of 6¾ inches, or about 200 feet per annum (217). The surface of the huge Baltoro Glacier, in the Karakoram Himalaya, moved on an average 5½ feet per day during two summer months (218); but for the whole year it must have necessarily averaged very much less. The surface of the Godwin Austin Glacier, in the same region, travelled rather less than a mile in seven years, or barely 2 feet per day—a much more reliable estimate. I imagine that we should halve even the minimum figure obtained in this way, to arrive at the rate of motion of the Ice Age glaciers, because they were not, on the whole, confined to valleys, but were driven forward by an impetus from each principal centre of accumulation, the slight but constant additions to which furnished the driving power; and these great centres were, there is the very strongest ground for believing, almost flat. Moreover, the ice which moved from Keewatin to the Mackenzie (800 miles) actually travelled uphill most of the way.

Length of Interglacial Stages.

Furthermore, after each ice invasion had terminated, a long time must have elapsed during which the frozen ground was thawing and the water draining away, ere even a single seed could take root upon the barren lands that remained; and we may be sure that the numerous animals, remains of which have been cited above, and which followed the vegetation after it had become well established, did not migrate northwards *en bloc*, but crept on far more gradually than they had previously died away. And as one goes more narrowly into the history of these times than is permissible in this book, and contemplates the innumerable places where the ice halted and again temporarily advanced during each retreat; and then the masses of loess, many feet thick, yet each thin layer the product of a sun-dried river dust; and the traces of lakes that have long since been drained; and the beds of slow-forming peat; and then reflects on the vast variety of the animals which again peopled those parts, only to die away and be replaced once more by the frigid conditions of continuous winter; and finally, when one remembers that all this went on four times in succession, the time we have named above seems scarcely adequate instead of too much.

Estimate of Post-Ice-Age Time.

We now come to the short period since the last Wisconsin glaciers melted away. This time is estimated from observations long continued and most carefully conducted, on the rates of recession of the Falls of St. Anthony, near Minneapolis, and of the Niagara Falls (Plate 33).

The Falls of St. Anthony have been in existence since the withdrawal of the ice from their site, and the rate at which the lip of the fall is being worn back has been observed ever since 1680; the facts indicate that 12,000 to 14,000 years have elapsed since the water first began to flow (219).

The Niagara gorge has been studied in the same manner; but, owing to their complicated history, and the varying volumes of water which have passed over them, the Falls are not such a reliable guide as the instance just cited. The lowest possible time for the existence of this waterfall is 7,000 years; but the Canadian Survey geologists consider 20,000 to 30,000 years

Pl. 104. *U* 304.

Tumbling Glacier, Mt. Robson.

Much of Britain was like this in the Ice Age.

Pl. 105. *U* 305.

The Great Irish Deer.

Antlers 9ft. 0in. across. This beautiful creature roamed over much of Britain during and after the Ice Age (p. 309).

as nearer the truth: there are very good reasons for placing the limits so far apart, and no useful purpose can be served by a closer approximation (220).

A third estimate of post-glacial time has been made in Alaska, in the White River district, where the last glaciation is believed to have been contemporaneous with the Wisconsin advance. By an ingenious marshalling of facts connected with the accumulation of vegetable remains there, Capps showed that some 8,000 years have elapsed since the ice left the district (221).

These three figures are so near one another, in a general way, that they may be taken as approximating very closely to the truth. Of what has transpired, physically, in those few thousands of years, we shall have something to say in the next chapter.

The Ice Age in Britain.

It now behoves us to look at home a bit; although the records of the Ice Age in our own country, while exceedingly numerous, are difficult to understand, more difficult to agree upon, and still more difficult to describe in a few general phrases (Plates 101, 102). If the Ice Age in America was regular, here it was irregular; if the former showed the gradual advance of large sheets over vast areas, here it shows, on the contrary, local advances over small areas, with a correspondingly greater complexity in the debris which the ice has left behind.

There were three glaciations at least in North-West Europe, radiating from Scandinavia. The first deposited erratic blocks near Aberdeen, but did not reach England. Cromer time, which followed, is the equivalent (I believe) of American Yarmouth time. Then came the Maximum Glaciation, when local British ice fought with and warded off that from Scandinavia.

Pre-glacial Britain.

Now, for a small country, Britain has a very diversified relief, and before the Ice Age it was still more rugged than at present. It is certain that in the higher areas, once the long winters and short summers had become a regular thing, snow-fields accumulated, and small glaciers flowed down into the surrounding lowlands, long before the advent of general ice-bound conditions. Such tracts of white-crested upland were to be found in the Welsh and Cumbrian mountains, in the Pennines, the Cheviots, and the Highlands of both northern and southern Scotland. In Ireland, which forms more or less of a plain in a frame of mountains, the latter became ice-flecked, and the glaciers moved down to help fill the plain. Probably, also, the snow often lay deep on Dartmoor, as it was destined to do for many a long year, whilst the white walls of the ice gleamed on the Welsh side of the Bristol Channel. The land connection with the Continent still existed, and such living things as could, fled, one after another, into the plains of France or the forests of Belgium. The rivers became so cold that much of their vegetation perished; whereby the fish suffered. In the great forests, now silent and deserted, the buds were killed with cold, and the lordly monarchs of the woodland, the oak, the beech and the elm, perished where they stood. Over all the country there stole a kind of terrible calm, as of a brooding calamity; and we may well imagine what hope there was for the future, in a land where every day was as grey and cheerless as the last.

Advance of the Ice.

In precisely the same manner as elsewhere, the snouts of the glaciers, ever moving farther and farther from their sources, gradually coalesced in some favourably situated basin; and when snow had filled it, the ice poured out, often under extreme pressure, in all directions. In addition to many of these small basins, there were several ice streams which took one constant direction. One such spread out from the Welsh mountains to east and north-east, scattering its erratic blocks over the border counties. A little later, a very great ice stream, whose threefold source lay in the Southern Uplands of Scotland, in the Cumbrian mountains, and in the Pennines and Cheviots, slowly poured southwards, utilising the deep depression formed by the Irish Sea; impinging on the Irish coast on the one hand, and the main Pennine mass on the other. This glacier attained the most formidable dimensions. It swept bodily over the Isle of Man, carrying rocks uphill for hundreds of feet in the most casual way (222). Over the site of Manchester, it was not less than 1,400 feet thick, and it was 1,200 feet thick at Macclesfield. In the neighbourhood of Anglesey, the moving plateau encountered the Welsh ice, which it handled roughly, forcing it aside and even overriding it. But against the solid rocks the northern ice was forced to split. One branch passed over Anglesey and so down the seaway to Pembroke, where it once more overrode the land, as far as the southern side of Milford Haven. The other branch went south-east to Wellington and Shrewsbury, while a small tongue of it, the Aire glacier, crossed the Pennines and pushed down the valley of the Aire.

From the high ground in the backbone of England, other ice streamed down to the east as far as the coast on Teesside, and into the Vale of York farther south, where it gave rise to a number of minor glaciers. Various other glaciers radiated outwards from Charnwood Forest; and Birmingham thus became a central meeting place for nearly all the ice in the country. Meantime, the North Sea was frozen out of existence; and a great glacier, travelling down the axis of the Baltic, and across Holstein and the Netherlands, and carrying with it rocks peculiar to each of these localities, struck upon the Norfolk coast, and buried the eastern counties deep, nearly as far as the valley of the Thames.

Scotland buried under Ice.

During all this time, each of the higher areas of Scotland had become a centre of intense glaciation: each district had its ice streams, which eventually became one common whole, though retaining, in part at least, their individual directions; and only summits well above 3,000 feet high escaped submergence. Those glaciers which defiled to the east were met by a stream moving south from Norway down the bed of the North Sea; and at places, such as the north coast of Aberdeen and the coast of North Yorkshire, the pressure caused by the opposing streams in collision was terrific: in the former area slices of the sea-bed were borne up bodily and dumped down on the land, in defiance of local opposition. But on the west, the ice had nothing to encounter but the broad Atlantic; and there it terminated in a mighty wall, extending over 1,000 miles from Shetland to Cape Clear. In this connection, it is interesting to note that the deposits of this ice sheet have been dredged repeatedly from various places on the submarine Wyville-Thomson Ridge.

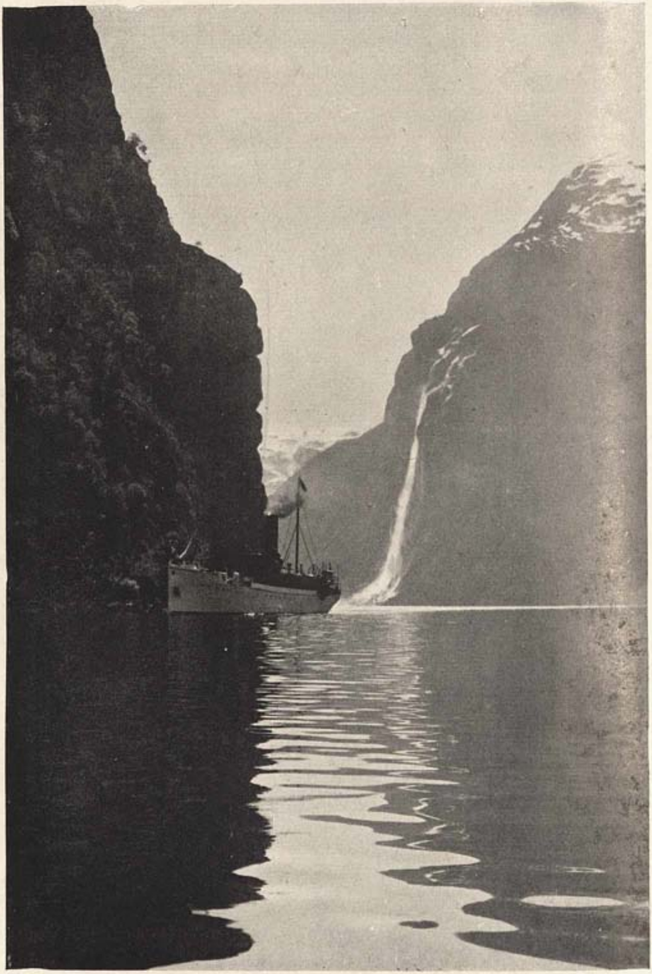
Supposed Interglacial Stage.

How long this condition of things endured no man can say; but that it was a considerable while is shown by the great numbers of erratic blocks from the Lake District and the Southern Uplands of Scotland which are found in the centre of England and the south-west of Wales, over 200 miles away. Finally, however, the ice retired. It is a matter of controversy whether or not it completely left these islands; but there is

Pl. 106. *U* 309.

The Mammoth.

The lord of the Ice Age, it ranged over the whole of the northern hemisphere, and was equal in bulk to the modern Indian elephant (p. 294).



Pl. 107. *X* 309.

A Norwegian Fjord.

Deepened and U-shaped by the Ice (p. 311).

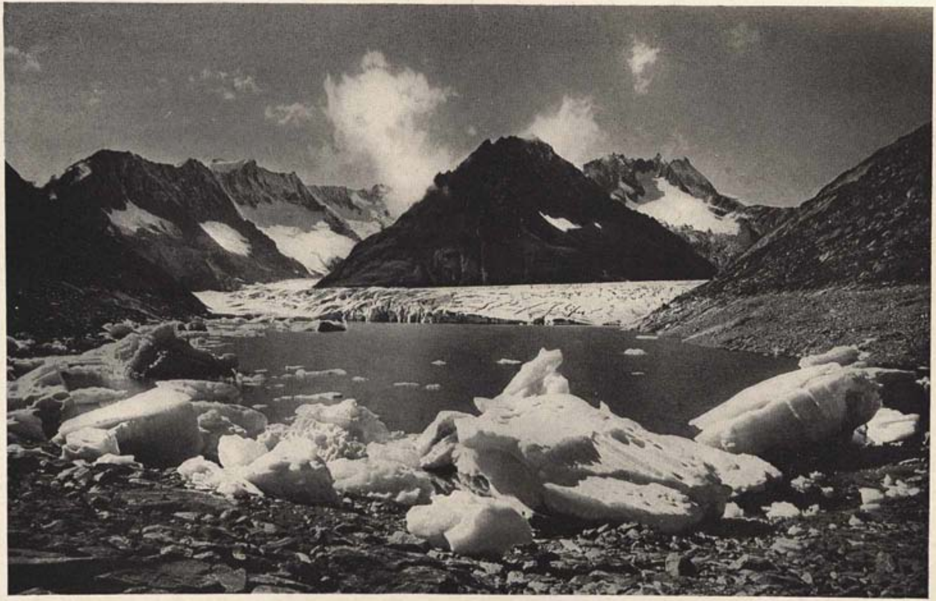
Photo. Wilsse.

reason to believe that it withdrew to North Scotland, when a mild stage set in, which lasted long enough for beds of peat to form, and for some remarkable changes in the physical geography of the times. There was in the area of North Wales, Cheshire and the neighbouring lands a considerable depression below sea-level, in places to as much as 400 feet. In the Macclesfield district, at that height above the sea, have been found marine shells of this time (224); while a number of wave-worn caves at about the same altitude dot the fair lands of North Wales—notably, the Cae Gwyn Caves, in the Vale of Clwyd, in which the remains of many animals, believed to be interglacial, have been found. Among these animals were the lion, wild cat, hyæna, bear, wolf, fox, wild boar, great Irish deer (Plate 105), reindeer, ox, mammoth, rhinoceros and horse (225): a singular commentary on the cosmopolitan tastes of the hyænas which, in all probability, were the actual denizens of these caves. Peat beds, probably of the same age, which have been found in Lincolnshire and Holderness, have yielded remains of oak and fir trees, horses, the mammoth and the elephant, and also brackish-water molluscs. Similar deposits, of which the age is doubtful, have been found in counties south of the Thames, and beyond the limits of the ice sheet. All the remains which have been found within the glaciated area indicate a cold, but not an Arctic climate. In the Cae Gwyn Caves flint implements were found; they form one of the earliest traces of man in this country north of the Thames.

Readvance of the Ice.

The conditions changed. The ice, which had never been very far away, returned in great force. All Scotland was once more wreathed in a shroud of white; but the glaciation this time was less intense than at first; and there were, apparently, none of the little feats of strength which the earlier ice had performed, such as moving blocks of Torridon Sandstone 1,500 feet up a hillside—a trick it accomplished during the major glaciation in the district of Loch Broom (226). Once more the east midlands of England rose above the waters; and once more they were buried in ice. Besides the local glaciers, there was a principal glacier (resulting from the filling of the large lowland basin of the Fens with *névé*), which sent out lobes in all directions: one stream flooded Suffolk on the east, and crossed the Chalk escarpment from Newmarket to Hitchin, then south-east into Essex, and south to Finchley and St. Albans, where its front lay for a long time stationary. Another broad mass from the same centre marched in silent grandeur straight into the heart of the country, burying Oxfordshire and impinging upon the Thames; while a third stream of ice moved northwards down the valley of the Trent. All these contained large quantities of chalk, torn from the Lincolnshire hills; hence, the whole system is known as the Chalky Boulder Clay.

The lower Thames at this time must have been a furious stream, wide and shallow, and flowing at a considerably higher level than at present; it carried the drainage of the edge of the ice sheet eastwards, past the chalk cliffs which then formed the coasts of Essex and Kent. Farther south, patches of snow and ice certainly lay on all the higher elevations. The English Channel, the "warm and sunny" of the holiday circulars, was a cold, windy, grey stretch of water, up which, like a phantom Armada, crept numbers of icebergs, which grounded and dropped their loads at shoals all along the coast: such debris has been found at Portland, Brighton and Hayling Island. There was still a land bridge across the Dover Straits; beyond which the bulk of the North Sea was certainly frozen over, for it formed the passageway for a large glacial stream from

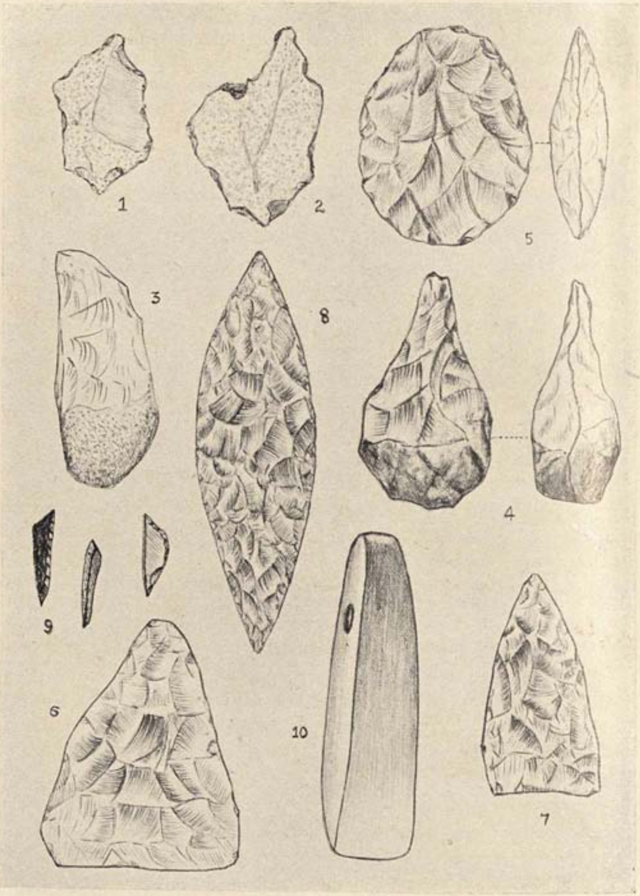


Pl. 108. *X* 310.

The Marjelensee, Switzerland.

A relic of the great Ice Age (p. 314).

Photo. Wehrli, Kildeberg.



Pl. 109. *X* 311.

Stone Implements (pp. 340-347).

1, 2. Eoliths; 3. Rostro-Carinate; 4. Chelles; 5. St. Acheul; 6. Le Moustier; 7. Aurignac; 8. Solutré; 9. Pygmy; 10. Neolithic Pick.

Norway, which crossed over to our shores via Jutland and the Skager Rak, only to be held up by the local ice.

Clear Evidences of the Ice Age.

To those who dwell in our fair cities, and daily use all the conveniences of civilised life, this must seem an England too strange to be possible; yet nothing is more certain than that such conditions did exist, and in a period when man was in existence. I have throughout this book felt the difficulty of inducing my readers to believe some of the strange facts that I have had to narrate; yet to those acquainted with geology they are commonplaces. It is only possible to fully realise the truth of all these things by a close study of the Earth book; but true they are, and if the reader can only master his instinctive distrust of believing that which his eyes cannot see, he will have advanced a great step along the road of Nature's mysteries. And indeed, in the Ice Age records, there is much, besides mud, clay, erratic stones and the like, of such a character that its message is obvious even to an untrained eye. Take, for instance, the striæ or grooves which mark the solid rock in numberless localities. Nothing but ice, and that land ice, so far as human knowledge extends, could make such marks. And of their relative recency—what is 10,000 or 20,000 years, except to the animal Man?—we have equally clear proof in their wonderful preservation. Rain has not pitted them, nor frost destroyed the smoothness of the ice-scoured surface. Even in the most exposed and elevated localities this is occasionally true; for instance, Sir Archibald Geikie has to say of the Highlands of Scotland:

"The quartzites of the west of Sutherland and Ross, as might be expected from their remarkable durability, have retained in singular perfection the polish and fine striæ imprinted on them by the ice sheet. The summits capped with these rocks have preserved their ice-worn surfaces so well at heights of even 3,000 feet, that where they plunge in precipitous sheets down the mountain sides, they cannot be walked upon. Even the sure-footed red deer, when tempted to cross these declivities, often lose their hold and are dashed headlong to the bottom" (227).

Post-glacial British Lakes.

The termination of the Ice Age in these islands was marked by the same phenomena, on a very much smaller scale, as in Canada and the United States. The glaciers withdrew to their gathering grounds by stages, leaving moraines in some places, and late-glacial lakes in others. A number of such small lakes existed in the Cheviot Hills and in the Lammermuirs: the sites of the outlets now form curious dry valleys or combes, formerly the subject of much speculation. There was a large late-glacial lake in Oxfordshire, the outflow of which is believed to have passed through the singular gap in the hills at Goring. There were many such lakes in the Highlands, of course; some of them have left considerable sheets of water as remnants of their former glory, others are only marked by the beach lines that they engraved upon their hilly shores—the greatest of these is the "Parallel Roads" of Glen Roy. In the north of Scotland, and in the Outer Hebrides, where the bare Lewisian Gneiss forms much of the surface, the relics of the once mighty glaciers are contained in thousands of tiny tarns. When confined to the Highland corries, a minor readvance of the ice occurred; but at last it vanished completely.

Slow Elevation of the Land.

While the ice was in slow retreat, and before it had gone very far towards its disappearance, much of the northern part of Britain, including the whole of Scotland, stood at a level about 100 feet lower than at present. The glaciers emptied into the sea, at the same time as cliffs were being cut in the solid rock by the waves: thus, the lochs must have presented an appearance analogous in many respects to that of Patagonia to-day.

The recession of the ice was so slow, that as the land slowly rose out of the waters, other rock platforms and beaches had time to be formed, at levels of 75 and 50 feet above the present sea-level; when the latter was built plants had regained possession of the land. The reversion to glaciers immediately afterwards caused moraines to be laid on the 50-ft. beach, and Arctic plants to grow in Norfolk.

It now behoves us to pass around the world in rapid survey, and see what was doing elsewhere during the Age of Ice.

The Ice Age in the Alps.

Of all the many proofs of the ice invasions, none are more clearly expressed than those of the Alps. Prior to Pleistocene times, this great mountain tangle had attained approximately its present outline, except that it was doubtless not so riven by frost, and it might have been a trifle lower.

As is well shown in the North-Eastern Alps, there were four distinct advances and retreats of the ice; elsewhere in the Alps, some of the valleys show traces of four advances, some of three, and some only of two. On each occasion, the phenomenon took the form of a great increase of ice in the main mass of highland, from which long glaciers of greater or less length stole down to the distant plains. The glaciers of the north-west, broad and gently sloping, extended in wide lobes down into the Bavarian, Swiss and French lowlands; and the Lake of Geneva's site was covered twice in this way. The more abrupt glaciers of the south, on the other hand, only just debouched upon the plains of the Po; while in the east, the glaciers never reached the limit of the mountains. "Sufficient explanation of these differences is found in the unequal altitude and snowfall of the glacial reservoirs, and in the unequal length and form of the valleys of discharge, as well as in the climate of the lowlands on which the ice ended" (228). The severity of the climate is well attested by the snowline, which was at times during this age some 4,000 feet lower than at present.

The four glacial stages—Gunz, Mindel, Riss, and Würm—coincided in time with the four stages of the Central U.S.A.; the interglacial stages have left us many plants and a few bones.

The Carpathians.

Farther east and north-east, the Carpathians form a great ring about the Hungarian plains. It is a curious fact that the inside of this ring was protected from invasion by the ice; most of the precipitation was on the northern side of the mountains, where the glaciers attained considerable magnitude, but became smaller and higher the farther one travelled east. In the South Carpathians and in the Balkans, traces of only two glacial stages have been recognised; the reason for this is that in mountain districts the later ice sheets tend to destroy the evidence of the earlier ones.

Ages of Rain.

The countries bordering the eastern end of the Mediterranean were during this age the scene of a phenomenon almost as curious as that of the ice sheet itself. Owing, in all probability, to the atmospheric disturbances set up by the intense cold in what ought, under normal conditions, to be the sunny regions bordering the Mediterranean, the occurrence of each ice sheet in the north synchronised with an age of almost continuous rain, or a "Pluvial Period." Thus, in Palestine, the first great Pluvial Period, or "Deluge," coincided with the first, or Gunz glacial stage of the Alps. It was also marked by the commencement of the Rift Valleys of that desolate land;

and instead of being 1,300 feet below sea-level, as at present, it was above the shores of the Mediterranean. There followed a short dry period, after which came a second great Deluge, which had been correlated with the second Ice Age, the Mindel stage, of the Alps. On this occasion, Lebanon was permanently snowclad in its higher parts, and glaciers descended into some of its valleys. To crown the misfortunes of the land—as if snow and rain were not enough—the Hauran became the site of several extensive volcanoes, whence great lava sheets invaded the Jordan valley. A vast inland sea filled most of the Jordan valley; Jebul Usdum, a mountain of salt 600 ft. high, rising white and statuesque from the edge of the Dead Sea, is a striking relic of the deposits left by this sea-bed as the water slowly evaporated away. The second rainy age was followed by a long dry one; and then by another, but smaller Pluvial Period, correlated with the third or Riss glaciation of the Alps. It is immediately after this that we get the first definitely known indication of man's existence in Palestine, stone implements having been found in many places. The dry age which followed was the beginning of the steppes and semi-arid climate which characterise the land to-day. Next, and last, came the Upper or Fourth Pluvial Age; according to Dr. Blanckenhorn, perhaps the best authority on these regions from our standpoint, this rainy age began some 50,000 years ago and ended some 10,000 years ago. It would be curious, if not profitable, to consider how much relation there is between these various Deluges and the great Deluge of the Bible; as to which, one can only remark, that legends of Deluges are common all over the Near East, many mountains besides Ararat having been indicated as the spot whereon men first regained possession of the land. From the scientific point of view, each "Deluge" was no more than a spell of continuously rainy weather; a universal drowning of the land over the tops of the mountains unquestionably never did occur.

The Ages of Rain were by no means confined to the Holy Land; for indications of three such ages have been detected in the Lower Nile. Much of Egypt, however, especially in the Eastern Desert, was a coral-studded sea at the commencement of Pleistocene times, the surface then being 900 feet lower than at present. As the age wore on, the land was gradually uplifted, and Africa and Asia united, the Mediterranean on the one side and the Red Sea on the other slowly withdrawing their shores. Afterwards, probably in the Pluvial times, a series of lakes, brackish or freshwater, developed in what is now the Nile Valley, into which igneous pebbles were swept by torrential streams draining the Red Sea hills. Subsequently, the barriers between this string of lakes were broken down, and the modern Nile is the result. There is no evidence of any glaciers ever having occupied the Red Sea hills (229).

Before leaving the subject of Rainy Ages, I should, perhaps, mention that they were also manifest in North America, in regions south of the glaciated zone, where two great freshwater lakes, known as Lakes Bonneville and Lahontan, are believed to have been formed by the flood waters in the wet spells, and twice drained during the dry spells. The tattered and relatively insignificant remnant of Lake Bonneville is now called Great Salt Lake; the shorelines of the older lake can be traced for many miles by the eye, along the surrounding mountains, and 1,000 feet above the valley (230).

Cooling of Tropical Africa and America.

As an indication of how general the cooling of the atmosphere was during the glacial epochs, the former levels to which glaciers stole in the snowy mountains of tropical Africa and the mighty Andes of tropical America, show a remarkable general agreement of level; a parallel which is maintained by their snow-lines to-day. In Glacial times, the level of permanent snow appears in both regions to have been 3,000 to 4,000 feet lower than it is at present. In the beautiful and mysterious Ruwenzori, the Mountains of the Moon, there are abundant traces of the work of the old ice rivers, which crept in places, as in the Mubuku valley, down to a level of 6,000 feet above the sea: and this spot is actually on the Equator.

Asia in the Ice Age.

Coming to Asia, we find there so many traces of the Ice Age that their abundance becomes a burden to the chronicler. But the geography of that vast tract of land was then very different in some parts from anything which exists to-day.

The principal changes were in the vertical relief. Large blocks of land, approximating to ovals in shape, have been raised, sometimes several thousand feet, *e.g.* along the middle course of the Hoang-ho; others have undergone depression, and this may account for the extraordinary hollow of Turfan, which lies below sea-level, although in the heart of the continent.

Glaciation has left abundant traces, its moraines occurring on most of the mountain ranges. Owing, however, to the slight precipitation, nothing more than mountain glaciers developed; and as such glaciers always tend to destroy the evidence of earlier glaciations, the story is far from complete. However, good evidence occurs of three glaciations in the mountains surrounding Lake Issyk Kul, and of two such stages in most of the other chains. Even in extreme north-east Siberia (where entire new ranges of mountains were discovered only four years ago) two glacial stages have been made out.

The Himalaya, of course, was thickly plastered with ice. In the Karakoram, moraines left by the old glaciers in the Nubra and Shyok Valleys may be discerned about 1,000 feet above the present streams, perched on ledges, eyrie-like (232). An important Italian expedition discovered, north of Kashmir, evidence of four glacial stages, with interglacial intervals.

On the Indus plains, as well as in Afghanistan, the ice tongues once stole down to within 3,000 or 4,000 feet of the sea.

A feature of Central Asia is its cold but beautiful lakes, whose surface of brilliant green or blue reflects the peculiar beauty of the sky. All these sheets of water were much swollen in glacial times; the old shores now run round them, up to levels of 400 feet above the water. This fact has been utilised to support theories of desiccation in Central Asia during recent times; but it is certain that the desiccation has been progressive, and commenced when the old (Wisconsin) glaciers died away, 15,000 to 20,000 years ago.

Human relics, or even bones of animals, are comparatively rare in the deposits of Central Asia; but the ubiquitous Mammoth roamed everywhere, and has been found from Persia to Mongolia, and from the Karakoram to the Arctic coast. As is well known, many of the carcases found in the Siberian lowlands were wonderfully preserved, even the flesh being capable of use as food for dogs.

The mountains of Japan are just too low to have been generally involved in the glaciation, nevertheless traces of it have been recognised in one place. A warm-water marine fauna found near Tokyo is probably interglacial. Farther north, Sakhalin remained cold and desolate; it paralleled the American coast of the Pacific, in that immense thicknesses of late Tertiary rocks were formed in narrow basins.

The cold of the Ice Age in no wise affected the volcanic activity of the East Indian chain, which continued throughout unchecked (Plate 93 B).

Australia and New Guinea in the Ice Age.

In Australia, we find the same evidence of a general cooling of the atmosphere as in the northern hemisphere. The snow-line of the Australian Alps formerly descended to 5,000 feet above sea-level; and the area between 5,000 and 7,000 feet was heavily glaciated. The same can be said even for New Guinea, where traces of the old glaciers in the Snow Mountains have been found at 13,300 feet above the sea, the present snow-line being 15,000 feet (234). In New Zealand, also, there are many traces of the ancient ice, at levels far below the existing ones. Here, owing to the softness of the rocks, enormous rubbish heaps or moraines were formed at the snouts of the glaciers, across the valleys; and when the ice melted away, water poured in between the moraines and the ice front, thus forming a number of barrier lakes—Tekapo, Pukaki and Ohau are examples. The glaciers have receded in recent times up to 40 miles from their points of maximum advance; and at the epoch of their greatest grandeur, they certainly emptied into the sea on the west coast, and also across the broad Canterbury Plains to the east of the island. Above beautiful Lake Wakatipu the ice was once 7,500 feet thick (235). Contemporaneously with this glaciation, North Island was still working out its destiny in a sea of liquid rock: probably in much the same manner, and with the same desolating results, as its modern eruptions exhibit.

A fact of immense significance to glacial theories is that Tasmania was glaciated three times (231).

ANTARCTICA.

Although Antarctica presents to us to-day the spectacle of a land mass larger than Europe, completely shrouded in an ice cap similar to those which formerly covered equally great areas elsewhere, the glaciation in those austral regions is by no means as extensive as it once was. At one time, in fact, the glaciers emptying into McMurdo Sound must have been many hundreds of feet thicker than they are now; for erratic blocks have been found scattered over the slopes of Mount Erebus, at heights up to 1,000 feet, and also on the summit of Mount Hope, 2,000 feet above the barrier surface (236). But as this stretch of coast is believed to be in the process of rising out of the sea, it is impossible to say just how thick the ancient glaciers were.

Burial of Patagonia under the Ice.

At that time, Patagonia, the nearest land to the frozen continent, was itself frozen hard, beneath a vast ice cap; while farther north, in Peru and Bolivia, rivers of ice of considerable magnitude descended far towards the plains. In Tierra del Fuego, the traces of this age are very marked. The strait between the land of fire and the mainland, by the way, is very modern, and probably post-glacial; but glaciation has not, of course, entirely ended there, some glaciers still debouching direct into the sea. It is interesting to note that in the lonely region of South Georgia there was a double glaciation, the earlier stage being much greater than the later: the same remarks apply to Patagonia, and the later climatic changes there so closely paralleled those of the Northern Hemisphere that only a world-wide cause (such as the Sun's heat) can have occasioned them.

The Ice Age in the Arctic Regions.

It is believed that Ellesmere and Heiberg Lands were never more ice-bound than at present (237), and some authorities believe the same to be true of Greenland. Parts of Greenland, however, show distinct signs of a formerly greater glaciation.

Immense quantities of driftwood of post-glacial age have been observed, by Nansen and others, on the ice-bound shores of Siberia, and on the north coasts of Ellesmere Land, Banks Land, etc.; and to explain its occurrence there one must postulate a milder climate, with a more open sea. There is generally believed to have been a short, warm spell which immediately followed the Great Ice Age; it coincided with

50-foot beach time in Scotland (p. 313), and was followed by a short but exceedingly severe return of glacial conditions, all over the world (*Buhl* time). This readvance has been noted in the Alps, in Scandinavia, in Britain, the U.S.A., Patagonia and the Himalaya. It had one remarkable consequence. The great mammals—the mammoth, the giant sloths, and the beautiful Irish deer—had successfully survived the vicissitudes of many glacial changes; but now they succumbed, and none are definitely known to have existed after Buhl time. Primitive man, then in the Magdalenian stage of culture, was forced to live in caves. There was no sign whatever of the amelioration which was so speedily to bring about the conditions under which we live to-day.

We have now passed in review, all too briefly, the principal facts of this short but all-important chapter of the Earth's story. Those of our readers who are sufficiently interested will find elsewhere several books devoted entirely to this age alone; and provided they can sufficiently disentangle the accurate from the picturesque, such books are well worth reading. It remains for us only to review the facts of man's early story, and the short but changeful time which has elapsed since the North American glaciers melted away; and our task is ended.

CHAPTER XIII.

The Age of Man.

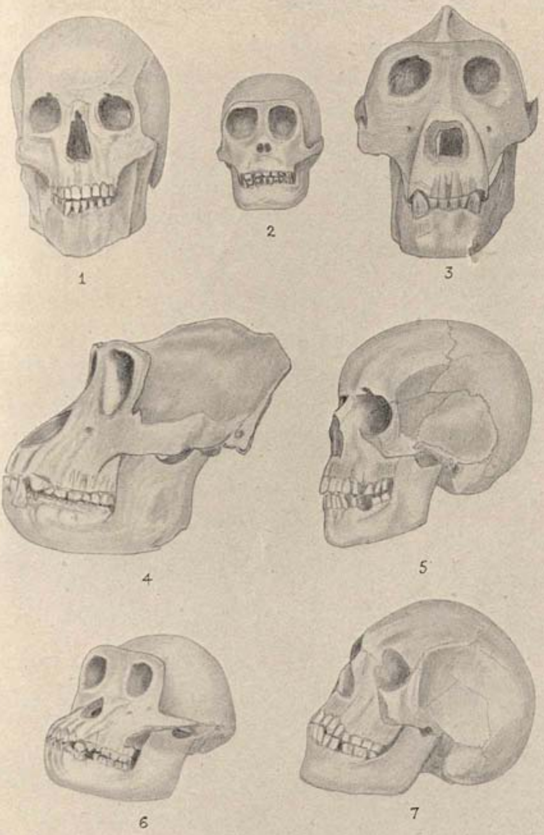
WE have now arrived at the last and thorniest part of our story: the origin and rise of man. The subject divides itself naturally into two parts—how man became what he is, and what kind of a world he originally lived in. We will deal with the former first.

DARWINISM.

So great a mass of evidence, good and bad, has been brought forward in the last half-century to demonstrate man's having been derived from lower animals, that it seems extraordinary that any intelligent person can deny the probability of such a thing; nevertheless, there are many people of very acute intellect who still feel unable to subscribe to the doctrine of "Darwinism." I can hardly hope to convince such readers, where far abler pens than mine have failed; nevertheless, as I believe in the evolution theory myself, I shall here set down what I conceive to have been the beginning of mankind.

PAUCITY OF FOSSIL HUMAN REMAINS.

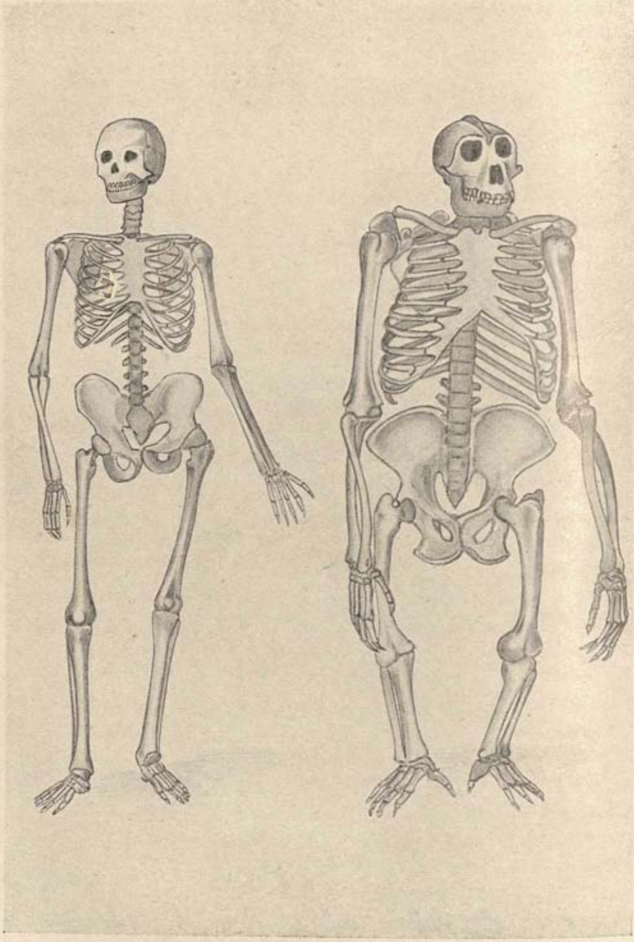
It must be premised that the subject is, and probably always will be, involved in the greatest obscurity. Men, and apes and monkeys generally, are not creatures whose remains are found fossil except under very special circumstances; and to this



Pl. 110. X 322.

Comparison of Human and Ape Skulls (p. 324).

1, 5. Caucasian. 2, 6. Chimpanzee. 3, 4. Gorilla. 7. Negro.



Pl. III. *X* 323.

Comparison of Human and Gorilla Skeletons (p. 325).

(After Du Chaillu).

paucity of skeletons is due the fact that many of the links in human development are hypothetical. Such remains as have been found, apart from those of a very recent age, are fragmentary in the extreme—skulls and parts of skulls, numbers of stone implements, and the like. The age of the deposits in which these remains were entombed is in more than one case open to doubt. Notwithstanding all this, however, there still remains a mass of facts that no amount of quibbling or denial can drive away.

Progressive Variation of Animals.

In the first place, it is generally agreed by educated people, even those who prefer to consider man as a special creation of the Almighty, that all animals and plants tend to vary, in a greater or less degree, without apparent purpose; and that of all such variations from a parent type, those only will survive which are best fitted to win in the struggle for existence. Thus, continual variation from a certain type does not necessarily mean that the *type* will die out: it may, and often does, persist longer than the variety to which it gave rise; and, of course, both parent and variant may exist side by side, each in an environment to which it is specially adapted or even both together. This is notably shown by the Brachiopod Lingula, which has persisted almost unaltered since Cambrian times; although enormous changes and variations among the descendants from the same stock have taken place in that vast period. It is also shown by many lowly forms of life, which only require simple conditions of environment to maintain their existence, such as the physical changes in the Earth's surface from one age to another have not affected; *e.g.* there is very little apparent difference between Carboniferous Foraminifera and those of to-day. On the other hand, the more highly organised an animal or plant becomes, the more liable it seems to be to destruction ; and if we accept the doctrine that there is a certain adaptation of every useful part of the animal to its surroundings, this liability to destruction becomes the necessary consequence of its being specialised ; for the physical conditions on the globe are constantly tending to alter, and so to force the organism either to adapt itself to the changed conditions, or to perish. Specialised animals, such as dinosaurs, giants, etc., cannot comply with this need ; consequently they die out.

Of actual adaptation of animals to changed conditions, there are numerous examples, which are recorded elsewhere. All I desire to emphasise here is that animals alter, both from an unknown tendency to vary indefinitely, and from the necessity of adapting themselves to changed conditions. Granted that, to explain the origin of man becomes much easier.

Earliest known Remains of Man.

The earliest known remains of man occur in interglacial deposits ; and although many attempts have been made to take his origin back to Pliocene times, or even farther, they have no foundation in observed facts. We will return to these remains in a moment.

Differences between Man and the Apes.

Now, men differ from their nearest allies, the apes, in a whole series of important particulars ; and yet, they are more closely allied to the apes than the latter are to lower monkeys. The essential differences between man and the apes are four in number—the relatively great size of the brain, particularly the cerebral hemispheres ; the power of standing erect, and the modifications in skeleton to which that has given rise ; the power of speech ; and the faculty of progressive thought, or intelligence, as distinguished from instinct. These various qualities overlap to a small extent in abnormal specimens both of men and of the apes; but they are salient distinctions, not to be lightly swept aside. The problem is to explain their origin.

It has been considered, on very good grounds, that man is not allied as closely to the higher apes—the chimpanzee, the orang-outang and the gorilla—as to the gibbous apes, or gibbons; the three types first mentioned are regarded as coming from the same stock, the gibbons, but having stopped at a certain stage in their development, whereas man, through acquiring the erect attitude of body, has developed much farther. The first progenitor of man may thus have been a hairy creature, living in trees; possibly a weak variety of gibbon, particularly prone to stand erect. Now, when standing upright, all the parts of the body are so arranged in man as to require a minimum amount of exertion in the performance of their various functions; and it is conceivable that the weak creature which stood erect in the branches compensated for its slightness by much greater agility: it would think more, and the tendency to think might be made hereditary, and so lead to a gradual increase in the size of the brain. The differentiation of the hands and feet, and the independent and more perfect use of these limbs, would also tend to increase the size of those brain centres which set them in motion. To cope more easily with the upright stance of the creature, the walls of its pelvis underwent certain changes, and many strong muscles had to be developed, in order to support the upright trunk; finally, it became natural to carry the head, not forward, but vertically on top of the trunk; and the fore limbs were brought back in a line with the chest (Plates 110, 111). All these developments must have been very gradual, the best of them being transmitted from generation to generation, possibly for long spells before another structural improvement took place, and it is important to note that successively younger human or quasi-human skulls, from mid-Pleistocene times onwards, show an advance on geologically older types. Eventually, however, man was really man, and no longer an ape; but he was a very primitive creature, with low brow, projecting jaw, brutish instincts, and most probably no power of speech, beyond the use of interjections. He is believed to have been of tropical habitat, it is not known in what part, and to have been small in stature: the nearest analogy that we can present to-day is shown by the pygmy tribes of Central Africa, Southern India and New Guinea.

EARLY MAN PROBABLY GREGARIOUS.

Early man probably lived in colonies, and thus the superior intelligence of one individual may have then, as now, powerfully affected the destinies of many less gifted men. Conversation in such colonies was probably mainly interjectional, even at a time when men had abandoned natural weapons and tools for those which they could manufacture; but eventually, a sort of speech grew up, and the faculty of articulation served two purposes—to increase the size of the head, and to exchange ideas. From this primitive speech all the modern diversity of tongues has arisen.

VARIATIONS IN SKIN; DISTRIBUTION OF MAN OVER THE EARTH.

The primitive man was dark-skinned; but those of his descendants who wandered far from tropical climes became more and more blanched, as they advanced farther north: this change being almost wholly a result of their environment. Thus, a fair-skinned, fair-haired race became established, many, many centuries ago, in Finland and the neighbouring parts of the Baltic. From this stock, it is believed that the white races have spread, in numerous waves of emigration, first over Europe, and later over the rest of the world. At the same time, very primitive types of men still exist, in the Pygmies of Africa and Australasia, in the Veddas of India, and in the Bushmen of South Africa; but they are slowly dying out, and their extinction is only a question of time. The story of the spreading of civilisation amongst men is beyond the scope of this book; but the interested reader will find numerous entertaining volumes devoted specially to that subject (233). We need only mention here, that when man began to use tools, he took the hardest and most readily accessible object he could find—to wit, flints that lay on the upper surface of the chalk, and pebbles of stone of a shape suited to his purpose. Later, he began to perceive the advantage of specially shaping stones for each particular duty; and many thousands of flint implements, or shaped stones, have been found as testimonies of early man's industriousness. In the next chapter we will devote a few pages to these interesting relics. Still later, he polished his stone tools; and later yet, he discovered the use of metals, using at first only the softer ones, until he learned to manufacture bronze. Each of these periods in the development of tools has been given a name; but it is quite certain that in those early days, as now, one race was familiar with the use of metals, while another still lingered in the ignorance of the Stone Age. An enormous impetus was given to man's development as a civilised animal by the discovery of iron, and its conversion into arms and implements; not the least result of which was an improvement in agriculture, enabling the land to support greater numbers. Hallstadt, in Austria, is believed to have been the first place in Europe where iron tools were made; the date is relatively modern, not exceeding that of the Roman Empire. Even in Egypt, iron is not known to have been used before about 800 B.C., and the Libyans had not the knowledge of it in 480 B.C. The earliest mention of it in China is 400 B.C. Bronze tools, on the other hand, go back at least to 3,000 B.C. in Egypt, and to 2,500 B.C. in Chaldea.

FOSSIL HUMAN REMAINS (257).

It remains but to review the principal discoveries of human or partly human bones which have been made.

The oldest remains, those of the celebrated *Pithecanthropus erectus*, were discovered in a stream bank, in Java, in 1890. They comprised a skull-cap, thigh-bone and some teeth. The skull-cap indicates that the animal was long-headed, intermediate between man and apes; the teeth are ape-like; the thigh-bone has marked human characters. The animal, as suggested by Boule, may have been a gigantic ally of the Gibbons; for giant creatures were common at this period—*e.g.* the sloths, beavers, etc. Along with the remains occurred bones of an elephant, similar to one which lived in earliest Pleistocene times in India. There were also numerous plants, indicating a cooler, wetter climate than at present. I believe Pithecanthropus to have been contemporary with one of the earlier glacial stages, probably the Mindel.

In sands at Mauer, near Heidelberg, a lower jaw was found in 1907, 80 feet beneath the surface. It is very brutish and ape-like, with a receding chin; but it contained all the teeth, which were notably human. The sands whence it came cannot be older than the last interglacial stage but one, and probably belong to the dawn of the last interglacial stage—*i.e.* they are much younger than Cromer Forest Bed time. Heidelberg Man may have been the precursor of the creature next to be described.

In 1857 there was discovered in the *Neanderthal* Cave, near Düsseldorf, a skull cap and some limb bones belonging to a primitive man. Subsequently other and better-preserved material has been discovered at various places in France and Germany, especially at La Chapelle-aux-Saints, which has enabled Neanderthal Man to be much better understood than any other primitive human race or species. Like Pithecanthropus, he was very long-headed. He was short, but extremely heavily built; with powerful teeth, long arms, low brutish chin, and enormous eye ridges. Casts of the brain case show primitive characters, but it was of large capacity.

The place in time of Neanderthal Man is fixed beyond all question. He lived in Germany during the middle of the last interglacial stage; and when the cold of Würm (*i.e.* Wisconsin) times came on, he was forced to retreat into caves and rock shelters, where he left his bones. He fashioned flint implements of the type known as Le Moustier (p. 343).

In 1921 a nearly complete skull was found at Broken Hill, Rhodesia, which has many affinities with Neanderthal Man, although in point of age it is probably younger.

Between the years 1911 and 1915, gravel in a field near Piltdown, Sussex, yielded broken portions of a skull cap and a lower jaw, which were carefully reconstructed by Dr. Smith Woodward. The skull was probably human, but the jaw has extraordinarily ape-like characters. There are no direct means of dating the remains, as they lie beyond the area invaded by ice; but they are associated with Pleistocene mammal bones, and with tools of Chelles pattern; thus, they probably belong to the earlier part of the last interglacial stage, when the temporary amelioration of the British climate occurred (p. 309).

In December, 1929, a skull was found near Peking which, according to Dr. Elliot Smith, possesses characters allying it to the Piltdown, Neanderthal and Pithecanthropus types.

Large caves near Mentone have yielded a rich series of human bones, including complete skeletons, associated with Ice Age mammals and the stone implements of several cultures. The oldest are some Negroid skeletons, belonging to an old woman and a young man, and having striking similarity to the modern Bushmen. These people sheltered there when the last glaciers overspread the neighbouring mountains, *i.e.* in Würm time. Subsequently, the climate grew milder, and a new type of man, not markedly different from modern races, overspread the Continent; from his cultural development, he is known as Aurignac Man. One race living during the earlier part of this mild spell, the Cro-Magnon Men, comprised individuals with an average height exceeding six feet; they were apparently very common in the south of France.

No more recent remains throw any light on human origins, because they so closely resemble existing skeletons.

From time to time various finds have been recorded, often with a great flourish of trumpets; but they do not invalidate the above sequence. The oldest human type that can be dated in relation to glacial deposits is that of Heidelberg Man, mid-Pleistocene. The other and younger types need not necessarily have been descended from him; indeed, modern opinion seems to lean to the view that there were several divergent races from a common ancestor who has not been discovered. In connection with the alleged existence of Pliocene or older men, it should always be remembered that, although there is nothing inherently improbable in the circumstance, the development of the apes does not support that idea.

I believe that at times of great terrestrial changes, such as those induced by the Ice Age, animals with a tendency to alter take great leaps in development; and I believe that the Ice Age was the *cause* of Man's coming into being, and not merely a phase of geographical conditions through which he had to pass.

Finally, it should be mentioned that well-known human remains were found in Florida, in association with extinct mammals; but they are certainly post-glacial, and related to the modern Indians. Numerous other "human" remains have been reported from time to time in the vast bone repositories which overspread the Pampas; but these are all either recent, or not human.

Changes of Land Level in Recent Times.

It might have been supposed that the development of man was the signal for some stability in the Earth, and a cessation of those many changes at which we have glanced herein; but the concluding note of this book will be to show that such is not the case. Nature is completely regardless of man and all his works: she is still engaged daily, one might say, in pushing up the ground beneath him, and in generally altering his environment.

It will be remembered that at the close of the Ice Age a terrace had been cut by the sea around most of Northern Britain at a level roughly 50 feet above the present sea-level. The rise continuing, a much wider terrace at about 25 feet above the sea was cut: this is a feature which can be discerned by the most casual traveller; and it has influenced the growth of cities, many Scottish towns having been built upon it. The terrace is nearly as well shown in the coasts of the Irish Sea as in Scotland. After its emergence Neolithic Man (who used polished stone tools, and constructed canoes) occupied this platform near Edinburgh and Glasgow, and in the island of Mull. Meantime, the east, south and south-east coasts of Britain were also undergoing changes of level. Thus, in the vicinity of London, the melting of the ice sheet was followed by a period of upheaval, with pauses indicated by successive terraces in the Thames valley; until, some 5,000 or 6,000 years ago, the land stood 80 feet higher than now: this fact is well shown by a buried channel of the Thames near Woolwich (238). Subsequently, there was a gradual and intermittent subsidence to the present level, accompanied by the growth, whenever the movements ceased, of layers of peat. Buried in the muds of this subsidence have been found numerous interesting traces of early Britons—canoes, tools, etc.

This post-glacial elevation and later subsidence seems to have been very general all down the south coast, where "many of the river valleys were cut to a depth of 60 or 70 feet below the sea; and much of the English coast was fringed with a broad strip of alluvium, which probably almost connected our island with Belgium and France. The climate during this epoch was temperate; for in the lowest 'submerged forests,' the oak is the most abundant tree. Then gradual and intermittent submergence flooded the lower parts of the valleys, and caused them to be silted up by the deposits of rivers that no longer had sufficient fall to scour their beds. In some of the peaty deposits or old vegetable soils that mark stages of rest in the process of submergence, we find polished stone weapons and relics of cultivated plants and of domestic animals" (239). There is a famous submerged forest at Torquay, another at Salcombe, yet others on the Cornish coast and the shores of the Bristol Channel. All these changes, recent though they are, antedate the first arrival of the Romans in Britain.

During this time the southern part of Britain moved as a whole; for similar subsidences occur in Ireland, in the many harbours of the south coast, and in the drowned south-western shores. The submergence also affected the French shores of the English Channel; and it was probably the immediate cause of the opening of the Dover Strait.

Recent Variations in Climate.

Our climate has also varied as much as our shoreline in recent times. There is abundant evidence to show a number of climatic changes, minor on the whole, but yet sufficient to permit trees like the birch to live at much greater altitudes than is now possible. Thus, in the peat moors of the northern counties, "on the north-eastern slopes of the Cross Fell chain, in the basins of the Tyne, Wear and Tees, traces of former birch woods meet the eye everywhere. . . . This ancient forest appears to have run up nearly to the summits of the highest fells, plentiful remains having been found at 2,600 feet on Cross Fell, 2,500 feet on Knock Fell, and 2,350 feet on the Weardale Fells" (240). Similarly, in Scotland, post-glacial peat in the Cowal district contains stems of birch at 1,500 feet or more on Stronchullin Hill (241), and in the peat of the hills up to 3,000 feet elsewhere, similar traces have been found: all these occurrences are far above the present limit of trees in the respective districts. This milder climate extended over the whole of north-western Europe; and pollen grains in the peat show the same order of succession in the different countries.

Further Post-glacial Land-level Changes: Europe.

There are many evidences of post-glacial changes in level in different parts of Europe. That along the shores of the Baltic has already been referred to (page 21), and also the changes of level in the Neapolitan area (page 20). The latter may perhaps be allowed a few further remarks.

In pre-Roman times, much of Italy stood 40 to 50 feet higher than now; and prior to this (yet sufficiently recent not to have been destroyed by subsequent erosion) a series of wave-formed caves in the cliffs of Capri, 700 to 800 feet above the sea, testify to its former level; and similar caves exist on the mainland at Amalfi. This district appears to have remained stationary for long periods—perhaps hundreds of years; and then to have risen or sunk in sudden spasms, like the troubled breathing of a subterranean giant. The Roman harbour works on the coast of Posilipo, and the Bagni della Regina Giovanni, were originally at least 16 feet higher above the sea than they now are; and there is indisputable evidence of a similar subsidence at Pozzuoli and the celebrated Temple of Serapis (242). All these changes seem to be less in the nature of regional movements, however, than spasmodic manifestations of the molten rock which finds its outlets in the neighbouring cones of Vesuvius, Vulcano, Stromboli and Etna.

There is considerable evidence of minor changes in recent times in other parts of the Mediterranean, most of the movements being slight elevations of the shore. A trifling rise has been recorded at Pola, in the Adriatic (243); and a greater one in Catalonia and Languedoc (244); while at Nice, Ice-Age deposits, originally laid down in the sea, are now 190 feet above its level (245); similar but much older deposits in Sicily rise thousands of feet above their points of origin.

Many old shorelines, all post-glacial, may be traced along the coast of South-East Norway, far above the reach of the tides. Connected with these movements, and dating from the time of the ice-melting and the formation of post-glacial lakes, is the rise of Jamtland, in Sweden, to an extent of 720 feet (246). The locus of greatest movement lay along the Gulf of Bothnia; only by a very complicated series of changes has the modern Baltic acquired its shape.

AMERICA.

The American changes of this nature are many and varied; and the evidence for most of them is beyond all question. The zone of greatest change in the Americas has been along the Pacific, all the way from Alaska to Cape Horn: a vast area, throughout which profound changes in level have been effected during the ages that man has peopled the world.

In Southern Alaska, the mighty mass of Mount St. Elias is separated from the sea by a large, flat glacier, of the type known as piedmont. This glacier, the Malaspina, debouches directly into the ocean at Icy Cliff, depositing there large quantities of boulders and mud. Exactly similar deposits—the deposits of the Ice Age—are to be found in outlying "hills" which, but for the presence of the giant St. Elias, would themselves be considered mountains—the Robinson Mountains, 5,000 to 9,000 feet above the sea; and at heights of 5,000 feet, Ice-Age marine fossils have also been found, thus proving that there has been an elevation there of at least 5,000 feet since early glacial times (247). Farther south, the long chain of islands which ends opposite Seattle tell the same tale, though to a less extent. In the wild and lonely Portland Canal mining region, the post-glacial elevation has been at least 500 feet, while in Vancouver it has been from 250 to 400 feet (248); thus indicating that when the Ice Age closed, these island areas were still smaller and more scattered than they now are. Some of this elevation may have been spasmodic; for the whole region is liable to earthquakes—witness that of San Francisco, in 1906, with its heavy toll of lives, and the severe earthquake in Yakutat Bay, in September, 1899, when an uplift of 47 feet 4 inches maximum took place (249). It is significant that while these northern lands have thus been moving, subterranean activity in the form of eruptions has not been idle. The Mount St. Elias region was devastated by one great eruption in post-Ice-Age times; and a layer of volcanic ash, erupted some 1,400 years ago, was spread over an area of more than 140,000 square miles: it has been calculated that the ash, if gathered together, would fill a cube of side 10 miles (250).

Proceeding southward down the line of weakness, we come to the San Francisco region, the history of which during Ice-Age and post-Ice-Age times would fill a good-sized book. To quote a great authority who lives on the spot, "the movements of the region about the Bay of San Francisco in Quaternary time have been complex and uneven. The Marin Peninsula proper between Bolinas and the Bay of San Francisco has undergone marked depression, and with this depression may be associated the invasion of the Golden Gate by the sea. The east side of the Bay, in the vicinity of Oakland and Berkeley, has been alternately lowered and raised, the net result of the movements being an uplift. The Point Reyes Peninsula has certainly been uplifted more than 250 feet, and this uplift has been followed by a slight depression. On both coasts of the San Francisco Peninsula the evidence, though not so clear as that presented on the Marin Peninsula, indicates subsidence in late Quaternary time" (251).

We next come to Lower California, where we once more get into the gigantic. There appears in that region to be abundant evidence that the Pacific is now rapidly retreating. "Traces were found of the comparatively recent presence of the sea, even at the altitude of 3,450 feet. Not only did the mountain sides present all the appearance of the recent action of the surf, as on a rocky coast, but well-preserved marine shells were everywhere met with, of species still existing in the neighbouring ocean" (252).

In South America the same great forces have been at work. To the traveller who coasts along those barren shores, the raised beaches are often plainly to be discerned; in various parts they have been examined and described, although the original descriptions by Darwin have yet to be surpassed for accuracy and completeness. Near Lima, the raised shore-line is only some 80 feet above the present one; but as one travels south, it gets higher and higher, until we are well into four figures again at Valparaiso; while farther south, traces of human occupation and of animal life have been met with in the mountains at elevations which to-day would be impossible. Still farther south, however, though in the same line, and operating apparently at the same time, the action has been exactly the reverse: the valleys between the mountains having been deeply drowned, and the outer Cordillera reduced to a chain of islets. Near Lake San Rafael, immediately south of the Gulf of Peñas, forests have been observed below sea-level, with the trees still standing. This depression extends over 12 degrees of longitude, and probably much more. The great plain east of the Andes, extending 700 miles south from Bahia Blanca and 200 miles inland, has also had its vicissitudes; it is of glacial and post-glacial origin, and represents eight successive movements of elevation, with marine-cut cliffs often now far inland. Relatively near by, however, the Falkland Islands have been submerged since glacial times to at least 200 feet, and possibly 350 feet below the present level, and then raised again (253).

On the Atlantic side of North America we could catalogue contemporaneous changes of this sort unto weariness. It must suffice, in a breath, to say that New England generally is now some 25 feet below its level when the ice sheets melted away; that there is some evidence of subsidence in buried forests in the Carolinas; that Florida is at present fairly stationary on the east, though rising on the west; that there has been considerable subsidence, of undetermined extent but certainly many hundreds of feet, in the Gulf of Mexico (254); and that there was a serious sinking of the sea-bed off Jamaica, as a result of the 1907 earthquake, whereby the wharves of Kingston were rendered useless.

Evidence of these movements is not confined to the shores of the continent; for the glacial lakes, by their long and often intricate shorelines, afford a means whereby any changes since their formation can be registered. They show us, with the clearness almost of a diagram, that such changes actually were registered, even while the beaches were being formed along their shores; for, in their southern parts quite horizontal, the old shorelines rise at a progressively greater angle as one goes north; although, of course, they must once have been horizontal. Thus, in the case of glacial Lake Algonquin, the predecessor of the existing Great Lakes, once the horizontal plane is left, the first 57 miles of travelling northwards yield an average increase in elevation of 1·43 feet per mile: this gradually becomes greater, until it is at least 6 feet per mile. We have here the shore of a lake, whose age is approximately known, and whose history can be traced in great detail, varying from 607 feet in the south, to at least 883 feet in the north, above the level of the sea—a rise, in other words, of 276 feet. A later beach of the Great Lakes also shows similar facts; but the rise had now become approximately steady, averaging very nearly 6 inches for every mile of northward advance.

At the time when the last ice sheet melted in this part of the world, Southern Ontario, and the adjacent parts of Quebec and New York State, were some 700 feet lower than at present; the rise to the existing level has been gradual and is well shown by many traces, both along the Hudson River and in the St. Lawrence.

If we look at Africa, it is the same. The Algerian shore has come up from the sea, since those not very distant days when the glaciers of the Alps were deploying upon the plains of Lombardy. Of the rise of the Egyptian Red Sea coast we have already spoken. The vast low area through which the Jub River winds was very recently the spawning ground of fishes. A recent steady elevation along the whole of the Guinea coast has materially aided in the formation of the Niger delta. Even in the heart of the continent, in the Victoria Nyanza, evidence is forthcoming of Earth movements of this nature; the lake gauges showing small differential movements between the stations.

Recent Land-level Changes in Other Parts of the World.

And so it has been with Asia, and with Australia, with New Zealand, with the vast wastes of the Pacific. Opposite the Nassau Range in New Guinea, acres of dead trees now stand in the sea at low tide. In the Federal Territory of Australia, the scarp of the Blue Mountains has risen far above Penrith. Parts of Japan have moved, relatively to sea-level, 11·2 inches in ten years. The great eruption of Krakatoa in 1883 gave rise to a subsidence of the whole island, which now lies some 800 feet below the waters of the Pacific. On the other hand, there arose out of the same waters, on November 14th, 1904, quietly and in the most casual way, an island of volcanic origin, from a sea bottom 6,000 to 10,000 feet deep, and in a month it had become 480 feet high. There is literally no end to the list that can be given; but there is an end to my readers' patience, so I will refrain from adding further instances.

CHAPTER XIV

Ancient Stone Implements.

MERCATI, who lived in the days of Queen Elizabeth, was the first man to recognise that flint implements were not natural products. By most men, however, they were little regarded and less understood, until the first half of the nineteenth century; in fact, they were generally assumed to be natural curiosities or "thunder-bolts": a tacit proof that their shape required some explanation. It was Boucher de Perthes (ably supported by Sir Charles Lyell) who really established them in the public mind as the handiwork of ancient human beings.

Stone implements are usually made of flint, because of its frequency in the countries of western Europe, where pre-historic man was so common; but this was replaced by quartzite or some other hard rock, in parts of Africa, India, etc., where flint was unobtainable. The implements, whatever their material, may be divided at a glance into two kinds, *Palæolithic* and *Neolithic;* the former were unpolished and crude, occurring in both Pleistocene and Recent deposits, whereas Neolithic implements are usually well shaped, sometimes polished, and rarely date back more than 4,000 to 5,000 years. The most ancient tools of man were so roughly chipped that there is legitimate doubt as to whether their fractures were naturally or artificially made; but from this beginning there exists a complete series, through stones that were obvious artifacts made by chipping, to exquisite knives and lance heads made with infinite pains, the pieces having been removed by pressure. We will briefly review the entire sequence, starting with the oldest.

EOLITHS AND ROSTRO-CARINATE STONES.

Eoliths are flints or other stones which bear chip marks of doubtful origin. Accepted as genuine artifacts by Mr. J. Reid Moir, the late Sir E. Ray Lankester and others, they have aroused doubts in the minds of many other experts, especially the wise and cautious Boule.

Eoliths are often much larger than authentic implements; frequently they have no particular shape: they are chipped on one edge, or on both (Plate 109). When a piece of flint is struck a smart blow, and a flake is chipped off, a swelling or "bulb of percussion" arises beneath the point of impact; and the presence of this feature in Eoliths is accepted by the believers in them as proof of their fabrication. However, such blows may arise naturally, through the grinding of gravel or in other ways; and Eoliths have, in fact, been produced artificially by the rotation of flints in a chalk mill.

These controversial stones have been found on chalk downs and in gravel patches in great numbers. They have also been found (not unequivocally *in situ*) at Ipswich, beneath the till, and at Cromer on the foreshore. According to Boule, they may occur in any formation from the Eocene upwards.

I incline to the view that they are not genuine, for the following reasons. Firstly, the Cromer Forest Bed, although it is unquestionably of interglacial age, and contains a rich mammal fauna, bears no trace whatever of human bones; nor are any equally old bones known from any part of the world, despite the most enthusiastic search for them. Secondly, the primitive men (or quasi-men) who preceded Neanderthal Man, lived much later than Cromer time, and were mere brutes.

When it occurred to one or more of them that stones could be shaped, I conceive that there would promptly occur a jump almost to the Chelles type of implement; for the intelligence of the mass of humanity remains at one dead level, and the genius who transforms their ideas often leaps vastly beyond the range of his fellows. Imagine mankind, in the bulk, even conceiving as possible in 1900 such things as broadcasting or flying! Because of this, I do not think that any tools much older than such as have obviously been fabricated—*i.e.* the proto-Chelles type—are likely to be artifacts. Finally, the breath of suspicion appears to be fatal. Any mark, any scratch, may be *imagined* as artificial; but of what value is such evidence in the absence of bones? Man goes back no farther than his remains can carry us, *i.e.* to mid-Pleistocene days; but Eoliths go back to the dawn of the great mammalian dispersal, far beyond the time when even primitive apes roamed the Earth.

Rostro-carinate stones (Plate 109) are on a rather higher plane than Eoliths, but not much. They also occur in East Anglia, and may date from Forest Bed time. They are rudely triangular, with one face flat; one end is roughly chipped into a beak-like curve, while the other has a natural roundness well suited for holding in the hand. Like Eoliths, these stones are considerably older than any known human bones.

The Chelles Type.

At Chelles, near Paris, in deposits which mark the commencement of the last interglacial stage, numerous flints have been found which have unquestionably been worked. They are associated with a fauna living under interglacial conditions—elephants, hippopotamus, Merck's rhinoceros, cave bears and hyænas, etc., and horses.

The most characteristic implement was the *point* or hand axe. The Chelles flints were coarsely chipped, some attempt afterwards being made to flatten them, and to produce a cutting edge: the latter, however, was wavy and irregular (Plate 109).

This type of implement has been recognised on many occasions in river gravel, notably in the Upper or Boyn Hill Terrace of the lower Thames. They date from a time when that river flowed about 100 feet above its present level, immediately after the first withdrawal of the north British glaciers. Similar implements were also found in the Piltdown gravel, along with Piltdown Man (Eoanthropus).

St. Acheul Type.

A little later Neanderthal Man roamed across central Europe; but in the meantime the Chelles pattern had been improved upon, better-fashioned implements having been unearthed at St. Acheul, on the Somme. The waving edge was straightened out, or transformed into a bold sigmoid curve; St. Acheul tools are also often well flattened, and disc-shaped (Plate 109).

This type of tool is also common in the Thames valley, besides having been found at Ipswich, between till from the two British glaciations.

Le Moustier Type.

Then came the Man of Neanderthal. As already explained, the climate became more severe some time after his first appearance, and he was forced to take up his habitat in caverns; accordingly, the implements which he employed are generally found in cave earth, or in the debris underlying rock shelters. From one such spot on the Dordogne the Le Moustier type of tool takes its name. Hand axes, tools for pointing, scraping and cutting, roughly made as a rule, are the characteristic varieties, a particularly common one being a bluntly triangular stone (Plate 109).

The association of these implements with Neanderthal Man proves their age; moreover, at St. Acheul they occur in a rock stratum overlying the St. Acheul type.

Aurignac Type.

During the long and severe Würm Glacial Stage (the last main glaciation of the world) Neanderthal Man clung to his fastnesses, and perished there. When at length the sun's rays acquired sufficient power to melt the ice, and it became possible to live in the open, a few communities did so, especially in the south of France; many men, however, had become wedded to cave life, and from these holes in the Earth they made their forays and their hunts, there they practised their rites (including burial of the dead), and there they left the marks of their handiwork. The negroid Grimaldi Race, of Mentone, is the oldest known type of post-Würm Man; his immediate successors were not physically distinguishable from modern men.

This was the Reindeer Age; for that useful creature roamed over practically the whole of Europe, and was the prey of the savages, and the subject of many of their drawings. The mammoth, woolly rhinoceros, cave hyæna, and giant sloths still existed. The climate, as shown by numerous leaves and fruits, was if anything a trifle milder than at present.

A number of discoveries in caves and shelters has proved beyond question that European men of this period underwent a succession of cultural advances, so far as the fabrication of stone was concerned; for the implements of the various stages have been found above one another, always in the same order.

The Le Moustier type, relic of the icy past, frequently occurs at the bottom. The oldest stones attributable to the new conditions are named from a cave at Aurignac, on the Upper Garonne. The finish was better than that of Le Moustier; and we now find notched tools, besides the more ordinary kinds; the hand axe was going out of fashion, and stone needles were made (Plate 109).

Shortly afterwards bone came to be generally employed. If, therefore, the reader should chance upon an ancient bone implement, he can be certain that it does not antedate the last glaciation, whatever its apparent antiquity may be.

Aurignac man lived on the chalk hills of southern Britain. He had such need of flints that he dug pits in the chalk to obtain them; and these were used by subsequent generations of savages. The pits, which were excavated by means of reindeer horns, occur mainly at Grimes' Graves, Brandon, and at Cissbury. They have yielded an enormous number of fabricated flints.

Solutré Type.

A vast improvement in workmanship occurred shortly afterwards, when the tool maker, patiently applying pressure to the finest and thinnest material, produced lance-shaped flints by thousands, often of exquisite delicacy of workmanship (Plate 109). They are named from a rock shelter in France, and are far more common on the Continent than in this country, one locality having yielded 30,000 of them.

La Madeleine Type.

The warm spell died away. The severe cold of Buhl time (p. 321) succeeded, bringing in its wake the extermination of the mammoth and other large mammals, besides driving the primitive races of men back into their caves. The craftsmen lost much of their skill at stone working ; by way of compensation, however, they began to blossom forth as engravers on bone, and produced many striking figures of battle and the chase ; they also made extraordinary little statuettes. The stone tools were mixed with bone needles ; this was also the first period of harpoon manufacture, there being a regular sequence from harpoons with barbs on one side to others that are doubly barbed. La Madeleine Man was also responsible for the very striking cave paintings at Altamira.

Mas d'Azil Culture.

Much less common is a type of tool which was transitional between Palæolithic and Neolithic times, and which is named from the Mas d'Azil Cave, Ariège. These implements occur on the 25-foot raised beach of western Scotland.

Pygmy Implements.

At about the same time many workers employed a curious series of pygmy implements, probably for engraving and other special purposes. They occur in association with numerous deposits of the Reindeer Age, and are common even in India (Plate 109).

Maglemose Culture.

Another transitional stage to Neolithic man was found at Maglemose, Holland, being typified by certain bone harpoons. The Maglemose men were fishermen, and immediately preceded the builders of kitchen middens.

Neolithic Implements.

Still younger are the latest of the ancient stone implements, the Neolithic. Picks, celts and axes form the chief types

(Plate 109); they are often bored, and have sometimes been found with the haft. Neolithic implements are usually smooth and regularly shaped, but are not always polished. Besides the heavier tools, there was a reversion to the beautiful work of Solutré time, typified by a boomerang, or sickle-shaped implement, and by daggers, saw blades, etc. Neolithic implements are mostly 3,500 to 5,000 years old.

Distribution of Stone Implements.

Although, as has been seen, the chief centres of culture were in western Europe, the occurrence of stone implements is world-wide. They are found in northern China, underlying the upper Loess of the Hoang-ho. Some of the Reindeer Age occur at Irkutsk. Large numbers have been retrieved from India and Australia; while Egypt was a veritable storehouse of them. They are much less common in the Americas; and apart from a few doubtful ones in the mid-glacial deposits of Iowa, the oldest occur in post-glacial beds in New Jersey.

Their Age Value.

Unfortunately a practice is growing up of dating unfossiliferous deposits by the implements they contain. This, in my opinion, is radically wrong. The implements, whatever their character, have no age value, apart from their associations with other fossils, for they are of human manufacture, and can have been flung away anywhere, and successfully buried by Nature in a dozen ways. Far different is it with the dead mammal or shell, whose remains are usually trustworthy indicators of age.

CHAPTER XV.

Whither?

OUR task is ended. We have surveyed, all too briefly, the whole long history of the Earth, so far as it is revealed in the Stone Book. Many an interesting nook has had to be passed by in this rapid transit, which further study will bring to the reader's notice; many anomalies, around which red-hot controversies have raged, have had to be merely glanced at, or omitted altogether. Yet with all these sins of omission and commission, I trust that our journey together has not been wholly uninteresting, or wholly unprofitable. If I have succeeded in awakening an interest in the past of the Earth, and a desire to pursue this branch of knowledge farther, I shall have achieved my object.

It remains but to consider one aspect of our science that has so far played no part in our rambles—to wit, the future. It is impossible to reflect on the long and continuous series of changes that have taken place, not only in the face of the globe, but also in all its inhabitants, without speculating upon what is going to happen to that globe and to that life in the future. The existence of man does not stop these natural changes in the smallest degree; and we may take it as absolutely certain that in the future the face of the Earth will become materially different from what it is to-day. How will those changes affect animals and plants? It is impossible to say. If, as is wholly possible, the present state of the northern hemisphere is but an interval between two stages of the Ice Age, then the whole of the area that once lay beneath the ice may again become a frozen desert, almost bereft of living things. But it seems more likely that the animals and plants of the world will change in the future, far more rapidly from the interference of man, than they ever did in the past without him. Bison he has hunted to destruction ; lions, tigers, wolves, and other beasts of prey are as surely marked down for practical extermination as if the governments of the world had decreed their ruin ; many birds have perished in the very recent past, and many more will certainly do so in the near future, unless legally protected. The breeding of animals has produced horses, to which past times can offer no comparison ; the crossing of plants has had and is having a like effect in the vegetable kingdom. Thus, it seems safe to conclude that any changes of note in the life of the globe will, in the immediate future, be directly due to human agencies.

But what of man himself ? Will he change ? There is no evidence to show ; but there is also nothing to negative such a conception. It appears certain that man will go on multiplying in numbers until there is a balance between the world's population and the agricultural produce that can feed it. More and more semi-desert areas will inevitably be brought under cultivation ; and perhaps, in a few thousand years, men will be happy to live in places that to-day we should shudder at. Once the balance between numbers and food has been attained, man must pause, no matter under what polity he is ranged. By his skill in medicine, he has removed most of the natural checks, in pestilence and plague, that formerly kept his numbers under control, and although it seems unhappily far distant as yet, a time will certainly come when man will be welded into one homogeneous whole, and wars will be a thing of the past. But when there is not sufficient food to nourisn them, children will not be born. What will the future man do ? Presumably, then, as now, a relatively small part of the human race will be engaged in agriculture, and a far greater part in the production and distribution of goods. This seems to indicate a possible greater brain capacity, combined with a tendency to weaken the physical capacity of the race. Beyond that point, in my opinion, no reasonable speculations can go. No one—not even the most daring brain—can hazard a guess. In any event, as a practical person would be quite justified in remarking, we shall not be there to see.

REFERENCES TO AUTHORITIES.

ABBREVIATIONS.

Mem. G.S.E.=Memoirs of Geological Survey of England and Wales.
" G.S.C.=Memoirs of Geological Survey of Canada.
" G.S.I. =Memoirs of Geological Survey of India.
Q.J.G.S. =Quarterly Journal of Geological Society of London.
B.A. Rept. =Annual Report of British Association for Advancement of Science.
U.S.G.S. =United States Geological Survey.
G.J. =Geographical Journal.
Smithson. Misc. Coll.=Smithsonian Miscellaneous Collections.

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(1) SIR A. GEIKIE: Scenery of Scotland, p. **27**. 1901.
(2) W. S. BARCLAY: G.J., Vol. **33**, p. 25. 1909.
(3) SIR J. MURRAY: Scott. Geog. Mag., Vol. **3**, p. 65. 1887.
(4) J. JOLY: B.A. Rept., 1900, p. 375.
(5) T. H. HUXLEY: quoted in Geology of London: Mem. G.S.E., p. 103. 1909.
(6) A. CHÉLU: Le Nil, le Soudan, l'Egypte, p. 177. 1891.
(7) Composite by the author.
(8) H. J. L. BEADNELL: G.J., Vol. **35**, p. 389. 1910.
(9) W. H. WORKMAN: G.J., Vol. **35**, p. 125. 1910.
(10) E. RÉCLUS: The Earth, p. 255. 1872.
(11) E. RÉCLUS: *op. cit.*, p. 254.
(12) E. SUESS: G.J., Vol. **20**, pp. 517–522. 1902.
(13) Royal Commission on Coast Erosion: G.J., Vol. **38**, p. 599. 1911.
(14) J. S. GARDINER: G.J., Vol. **28**, p. 324. 1906.
(15) J. HJORT: G.J., Vol. **37**, p. 362. 1911.
(16) E. RÉCLUS: *op. cit.*, p. 239.
(17) E. RÉCLUS: *op. cit.*, p. 244.
(18) R. T. GÜNTHER: G.J., Vol. **22**, pp. 128–130. 1903.
(19) R. T. GÜNTHER: *op. cit.*
(20) E. RÉCLUS: *op. cit.*, pp. 531–532.

(21) W. A. E. USSHER: Geology of Torquay. Mem. G.S.E., p. 122. 1903.
(22) J. MILNE: G.J., Vol. **10**, p. 133. 1897.
(23) J. MILNE: Earthquakes, pp. 272–279. 1898.
(24) F. W. CLARKE: Data of Geochemistry, pp. 290, 356. 1920.
(25) J. W. JUDD: Volcanoes, p. 19. 1888.
(26) J. W. JUDD: *op. cit.*, p. 25.
(27) J. MILNE: G.J., Vol. **7**, p. 149. 1896.
(28) F. OMORI: Bull. Imp. Jap. Earthquake Com., Vol. **5**, pp. 1–38. 1911.
(29) T. ANDERSON: G.J., Vol. **39**, p. 128. 1912.
(30) T. A. JAGGAR: G.J., Vol. **32**, p. 623. 1908.
(31) ANON.: G.J., Vol. **43**, p. 208. 1914.
(32) SIR C. LYELL: Principles of Geology, pp. 4 *et seq.* 1847.
(33) J. D. DANA: American Jour. Science, pp. 455–462. 1892.
(34) E. A. SCHÄFER: Presidential Address, B.A. Rept., 1912.
(35) SIR A. GEIKIE: *op. cit.*, p. 125.
(36) L. W. HINXMAN: Structure of N.W. Highlands of Scotland. Mem. G.S. Scot., p. 275. 1907.
(37) L. W. HINXMAN: *op. cit.*, p. 274.
(38) L. W. HINXMAN: *op. cit.*, p. 274.
(39) W. J. SOLLAS: B.A. Rept., 1900, p. 721.
(40) T. C. CANTRILL and others: Geology of S. Wales Coalfield, Pt. XII. Mem. G.S.E., pp. 11–14. 1916.
(41) C. D. WALCOTT: Smithsonian Ann. Rept. for 1915, p. 242.
(42) C. CAMSELL and W. MALCOLM: Mem. G.S.C. 108, p. 55. 1921.
(43) H. V. ELLSWORTH: Summary Rept., G.S.C., Pt. D, pp. 51–70. 1921.
(44) A. C. LAWSON: Mem. G.S.C. 40, pp. 6 *et seq.* 1913.
(45) C. W. KNIGHT and others: 28th Ann. Rept., Ontario Bureau of Mines, pp. 13–17. 1919. Also 30th Rept. Pt. VI., pp. 35–42. 1922.
(46) F. D. ADAMS and A. C. BARLOW: Mem. G.S.C. 6, p. 33, 1910.
(47) H. A. NICHOLSON: Manual of Palæontology, Vol. **1**, pp. 125–129. 1879.
(48) ADAMS and BARLOW: *op. cit.*, pp. 115 *et seq.*
(49) E. C. HARDER: U.S.G.S. Professional Paper 113, p. 51. 1919.
(50) A. C. LAWSON: Mem. G.S.C. 28, p. 14. 1912.
(51) C. D. WALCOTT: Mem. G.S.C. 28, pp. 16–19. 1912.
(52) C. R. VAN HISE and C. K. LEITH: U.S.G.S. Bulletin 360, pp. 341–347. 1909.

(53) VAN HISE and LEITH: *op. cit.*, p. 56
(54) L. KOCH: Journal of Geology, Vol. **31**, p. 56. 1923.
(55) J. M. CLARKE: G.S.C., Guide Book No. 1, p. 94. 1913.
(56) C. D. WALCOTT: Smithson. Misc. Coll., Vol. **67**, No. 4, p. 124. 1918.
(57) C. D. WALCOTT: Smithson. Misc. Coll., Vol. **53**, No. 6, p. 241. 1910.
(58) C. D. WALCOTT: Smithson. Misc. Coll., Vol. **67**, No. 7, p. 431. 1921.
(59) C. D. WALCOTT: Smithson. Misc. Coll., Vol. **57**, No. 6, p. 162. 1912.
(60) C. D. WALCOTT: *op. cit.* (59), p. 149
(61) C. D. WALCOTT: Smithson. Misc. Coll., Vol. **67**, No. 5. 1919.
(62) C. D. WALCOTT: Smithson. Misc. Coll., Vol. **57**, No. 3. 1911.
(63) C. D. WALCOTT: Smithson. Misc. Coll., Vol. **67**, No. 6. 1920.
(64) C. D. WALCOTT: Smithson. Misc. Coll., Vol. **57**, No. 5. 1911.
(65) C. SCHUCHERT: Synopsis of American Fossil Brachiopoda, p. 89. 1897.
(66) T. C. CANTRILL and others: *op. cit.*, p. 19.
(67) H. C. SORBY: Q.J.G.S., Vol. **64**, p. 228. 1908.
(68) SIR A. C. RAMSAY: Physical Geology and Geography of Great Britain, p. 72. 1894.
(69) SIR A. C. RAMSAY: *op. cit.*, p. 73.
(70) J. M. CLARKE: *op. cit.*, p. 110.
(71) J. A. DOUGLAS: Q.J.G.S., Vol. **70**, p. 44. 1914.
(72) KORSCHELDT and HEIDER: Embryology of Invertebrates, Pt. I., p. 125. 1895.
(73) KORSCHELDT and HEIDER: *op. cit.*, p. 98.
(74) A. H. CLARK: Monograph of Existing Crinoids, Vol. **1**, Pt. I., p. 198. 1915.
(75) KORSCHELDT and HEIDER: *op. cit.*, p. 459.
(76) H. B. WOODWARD: Geology of London. Mem. G.S.E., p. 6. 1909.
(77) SIR A. C. RAMSAY: *op. cit.*, p. 96.
(78) SIR A. GEIKIE: *op. cit.* (1), p. 138.
(79) H. A. NICHOLSON: *op. cit.*, Vol. **2**, p. 454.
(80) HUGH MILLER: The Old Red Sandstone, Centenary Edn., p. 156.
(81) H. A. NICHOLSON: *op. cit.*, Vol. **2**, p. 149.
(82) HUGH MILLER: *op. cit.*, p. 237.

(83) HUGH MILLER: *op. cit.*, p. 96.
(84) H. A. NICHOLSON: *op. cit.*, Vol. **2**, p. 150.
(85) HUGH MILLER: *op. cit.*, p. 178.
(86) HUGH MILLER: *op. cit.*, p. 181.
(87) E. E. L. DIXON and A. VAUGHAN: Q.J.G.S., Vol. **67**, pp. 434 *et seq.* 1911.
(88) F. DIXEY and T. F. SILBY: Q.J.G.S., Vol. **73**, p. 157. 1918.
(89) G. BARROW: Geology of East Lothian. Mem. G.S. Scot., p. 65. 1910.
(90) W. J. SOLLAS: B.A. Rept., 1900, p. 740.
(91) E. HULL: Coal Fields of Great Britain, p. 100. 1881.
(92) E. HULL: *op. cit.*, p. 129.
(93) J. PHILLIPS: Manual of Geology, pp. 202–203. 1855.
(94) J. PHILLIPS: *op. cit.*, p. 189.
(95) J. PHILLIPS: *op. cit.*, p. 200.
(96) E. HULL: *op. cit.*, p. 105.
(97) SIR A. STRAHAN: B.A. Rept., 1904, pp. 534 *et seq.*
(98) SIR C. LYELL: Manual of Elementary Geology, p. 318. 1852.
(99) M. J. MUNN: Geologic Atlas of U.S.A., Folio 180, p. 9. 1912.
(100) H. HINDS and F. C. GREENE: Stratigraphy of Pennsylvanian Series in Missouri, p. 8. 1915.
(101) R. A. DALY: Mem. G.S.C. 38, Ch. 1. 1912.
(102) E. DE K LEFFINGWELL: U.S.G.S. Professional Paper 109, pp. 106, 125. 1920.
(103) P. SCHEI: G.J., Vol. **22**, pp. 62–63. 1903.
(104) L. L. FERMOR: Mem. G.S.I., Vol. **41**, Pt. II. 1914.
(105) L. DEPARC and others: Le Bassin de la Haute Wichera. 1909.
(106) A. DE LAPPARENT: Traité de Géologie, p. 918. 1900.
(107) A. DE LAPPARENT: *op. cit.*, p. 919.
(108) J. A. DOUGLAS: *op. cit.*, p. 30.
(109) A. C. SEWARD: Q.J.G.S., Vol. **78**, p. 278. 1922.
(110) J. A. DOUGLAS: *op. cit.*, p. 47.
(111) H. WOODWARD: B.A. Rept., 1906, p. 567.
(112) S. H. SCUDDER: Revision of American Fossil Cockroaches, p. 12. 1895.
(113) S. H. SCUDDER: *op. cit.*, p. 30.
(114) SIR C. LYELL: *op. cit.* (98), p. 335.
(115) H. A. NICHOLSON: *op. cit.*, Vol. **2**, p. 167.
(116) H. A. NICHOLSON: *op. cit.*, Vol. **2**, p. 457.
(117) H. A. NICHOLSON: *op. cit.*, Vol. **2**, p. 452.

(118) E. Hull: *op. cit.*, p. 65.
(119) Sir A. Strahan: *op. cit.* (97), p. 538.
(120) E. W. Claypole: B.A. Rept., 1884, p. 718.
(121) B. Willis: U.S.G.S. 13th Ann. Rept., Pt. II., p. 269. 1894.
(122) The Everest Expedition Report: G.J. 1923.
(123) J. W. Gregory: B.A. Rept., 1906, p. 576.
(124) J. A. Douglas: *op. cit.*, p. 47.
(125) F. E. Studt: Trans. Geol. Soc. S. Africa, Vol. **16**, p. 93. 1914.
(126) J. Park: New Zealand Geol. Surv. Bull. 23, p. 41. 1921.
(127) Sir A. Geikie: *op. cit.* (1), p. 335.
(128) N. H. Darton: U.S.G.S. Bulletin 715, p. 205. 1921.
(129) H. H. Hayden: Mem. G.S.I., Vol. **36**, Pt. I., pp. 82–84. 1912.
(130) T. H. D. La Touche: Mem. G.S.I., Vol. **39**, Pt. II., p. 355. 1913.
(131) H. H. Hayden: Mem. G.S.I., Vol. **39**, Pt. I., pp. 78–79. 1911.
(132) T. G. Bonney: B.A. Rept., 1906, p. 574.
(133) A. de Lapparent: *op. cit.*, p. 1035.
(134) F. W. Clarke: *op. cit.*, p. 223.
(135) G. W. Lamplugh: B.A. Rept., 1905, pp. 298 *et seq.*
(136) C. L. Baker: Journal of Geology, Vol. **31**, p. 69. 1923.
(137) H. A. Nicholson: *op. cit.*, Vol. **2**, p. 288.
(138) J. Lomas and others: B.A. Rept., 1907, p. 305.
(139) M. G. Mehl: Journal of Geology, Vol. **30**, p. 156. 1922.
(140) H. A. Nicholson: *op. cit.*, Vol. **2**, p. 222.
(141) R. Ruedemann: Journal of Geology, Vol. **30**, pp. 311 *et seq.* 1922.
(142) J. Phillips: *op. cit.*, p. 286.
(143) G. E. Pilgrim: Mem. G.S.I., Vol. **34**, p. 58. 1909.
(144) T. H. D. La Touche: *op. cit.*, p. 356.
(145) J. A. Bancroft: Mem. G.S.C. 23, pp. 102–104. 1913.
(146) O. C. Marsh: U.S.G.S., 16th Ann. Rept., Pt. I., p. 156. 1895.
(147) O. C. Marsh: *op. cit.*, pp. 166 *et seq.*
(148) O. C. Marsh: *op. cit.*, pp. 168 *et seq.*
(149) O. C. Marsh: *op. cit.*, p. 188.
(150) O. C. Marsh: *op. cit.*, p. 192.
(151) H. A. Nicholson: *op. cit.*, Vol. **2**, p. 192.
(152) R. B. Newton: G.J., Vol. **24**, p. 524. 1904.
(153) E. Hennig: Am Tendaguru. 1912.
(154) A. E. Kitson: G.J., Vol. **41**, p. 19. 1913.

(155) E. W. Berry: Maryland Geological Survey: Lower Cretaceous, pp. 92–94. 1911.
(156) W. T. Lee: U.S.G.S. Bulletin 510, p. 199. 1912.
(157) F. H. Knowlton: U.S.G.S. Professional Paper 101, pp. 223–235. 1917.
(158) W. W. Leach: G.S. Can. Guide Book No. 9, p. 39. 1913.
(159) W. W. Leach: *op. cit.*, p. 38.
(160) E. W. Shaw and P. L. Ports: U.S.G.S. Bulletin 716, p. 70. 1921.
(161) E. W. Berry: Journal of Geology, Vol. **30**, p. 226. 1922.
(162) Sir A. Geikie: Textbook of Geology, p. 1179. 1904.
(163) Sir A. Geikie: *op. cit.*, p. 1176.
(164) Sir A. Geikie: *op. cit.* (1), p. 169.
(165) Sir A. Geikie: *op. cit.* (1), pp. 170–172.
(166) H. S. Gale: U.S.G.S. Bulletin 715, p. 27. 1921.
(167) T. H. D. La Touche: Records of G.S.I., Vol. **21**, p. 162. 1888.
(168) A. de Lapparent: *op. cit.*, p. 1024.
(169) Sir C. Lyell: *op. cit.* (98), p. 189.
(170) W. Howchin: Evolution of Physiography of S. Australia. Rept. Austral. Assoc. Adv. Sci., 1913.
(171) P. G. Morgan: N.Z. Geol. Surv. Bulletin 6, pp. 34–35. 1908.
(172) J. M. Bell and C. Fraser: N.Z. Geol. Surv. Bull. 15, p. 52. 1912.
(173) R. A. Daly: *op. cit.*, p. 90.
(174) R. A. Daly: *op. cit.*, p. 91.
(175) W. Lindgren: U.S.G.S. Professional Paper 73, p. 81. 1911.
(176) W. Lindgren: *op. cit.*, p. 9.
(177) Composite by the author.
(178) H. C. Cooke: Mem. G.S.C. 96, p. 281. 1917.
(179) W. T. Lee and others: U.S.G.S. Bulletin 612, p. 39. 1915.
(180) W. T. Lee and others: *op. cit.*, p. 37.
(181) W. T. Lee and others: *op. cit.*, p. 40.
(182) E. W. Berry: U.S.G.S. Professional Paper 91, p. 72. 1916.
(183) A. Heim: Mechanismus der Gebirgsbildung, II., p. 211. 1878.
(184) K. Peucker: G.J., Vol. **19**, pp. 735 *et seq.* 1902.
(185) R. Hoernes, quoted in G.J., Vol. **35**, p. 448. 1910.
(186) G. E. Pilgrim: *op. cit.*

(187) P. and F. SARASIN: Notice in G.J., Vol. **20**, pp. 446–448. 1902.
(188) H. A. LORENTZ: G.J., Vol. **37**, p. 496. 1911.
(189) D. UHLIG: Zeitschr. Berlin Geog. Soc., Nos. 1 and 2. 1905.
(190) J. E. S. MOORE: G.J., Vol. **18**, pp. 1–36. 1901.
(191) J. E. S. MOORE: *op. cit.*, p. 13.
(192) C. W. ANDREWS: Q.J.G.S., Vol. **70**, pp. 163–186. 1914.
(193) F. OSWALD: Q.J.G.S., Vol. **70**, p. 140. 1914.
(194) P. G. MORGAN: N.Z. Geol. Surv. Bulletin 6, pp. 35–37. 1908.
(195) G. E. CHURCH: G.J., Vol. **17**, p. 334. 1901.
(196) G. E. CHURCH: *op. cit.*, p. 341.
(197) K. SAPPER: Verhandlungen, Berlin Geog. Soc., No. 8. 1900.
(198) SIR A. GEIKIE: quoted in U.S.G.S. Bulletin 199, p. 62. 1902.
(199) SIR E. H. SHACKLETON: G.J., Vol. **34**, p. 494. 1909.
(200) M. L. FULLER: U.S.G.S. Professional Paper 82, pp. 61–64. 1914
(201) R. BELL: G.J., Vol. **18**, pp. 25–45. 1901.
(202) F. NANSEN: G.J., Vol. **30**, p. 601. 1907.
(203) O. P. HAY: Pleistocene Mammals of Iowa, p. 31. Des Moines. 1914.
(204) O. P. HAY: *op. cit.*, p. 33.
(205) W. C. ALDEN and M. M. LEIGHTON: Ann. Rept. Iowa Geol. Surv., Vol. **26**, p. 121. 1917.
(206) B. SHIMEK: 20th Ann. Rept. Iowa Geol. Surv., p. 377. 1910.
(207) T. C. CHAMBERLIN and R. D. SALISBURY: 6th Ann. Rept. U.S.G.S., pp. 278–285.
(208) W. C. ALDEN: U.S.G.S. Professional Paper 106. 1918.
(209) E. DE K. LEFFINGWELL: *op. cit.*, pp. 142–149.
(210) See particularly, F. LEVERETT and F. B. TAYLOR: Mon. U.S.G.S. 53. 1915.
(211) W. UPHAM: Mon. U.S.G.S. 25. 1895.
(212) M. L. FULLER: *op. cit.*, pp. 195–216.
(213) R. A. DALY: *op. cit.*, pp. 577–598.
(214) W. W. ATWOOD: U.S.G.S. Professional Paper 61, pp. 65, 91. 1909.
(215) O. NORDENSKIOLD: G.J., Vol. **38**, pp. 282–283. 1911.
(216) SIR E. H. SHACKLETON: *op. cit.*, p. 499.
(217) H. PALMER: G.J., Vol. **39**, p. 448. 1912.
(218) F. DE FILIPPI: G.J., Vol. **37**, p. 20. 1911.

(219) F. W. Sardeson: Geologic Atlas of United States, Folio 201, pp. 12–13. 1916.
(220) F. B. Taylor: G.S.C. Guide Book No. 4, pp. 49–53. 1913.
(221) S. R. Capps: U.S.G.S. Bulletin 630, pp. 69–74. 1916.
(222) G. W. Lamplugh: Geology of Isle of Man. Mem. G.S.E.
(223) T. I. Pocock: Geology of Macclesfield, etc., p. 79. Mem. G.S.E. 1906.
(224) T. I. Pocock: *op. cit.*, pp. 83–87.
(225) H. Hicks: B.A. Rept., 1885, pp. 1021–1023.
(226) B. N. Peach and others: Geology of Fannich Mts. Mem. G.S. Scot., p. 105. 1913.
(227) Sir A. Geikie: *op. cit.* (1), pp. 276–277.
(228) W. M. David: G.J., Vol. **34**, p. 653. 1909.
(229) Barron and Hume: Geology of Eastern Desert of Egypt (Central Portion). 1902.
(230) G. K. Gilbert: Lake Bonneville: U.S.G.S. 1890.
(231) A. N. Lewis: Rep. Austral. Assoc. Adv. Sc., pp. 86–90. 1926.
(232) T. G. Longstaff: G.J., Vol. **35**, pp. 626, 640. 1910.
(233) See esp. W. J. Sollas: Ancient Hunters. London. 1915.
(234) H. A. Lorentz: *op. cit.*, p. 500.
(235) J. Park: N.Z. Geol. Surv. Bulletin 7, p. 36. 1909.
(236) Sir E. H. Shackleton: *op. cit.*
(237) P. Schei: *op. cit.*, p. 65.
(238) H. B. Woodward: *op. cit.*, p. 94.
(239) H. B. Woodward: *op. cit.*, p. 98.
(240) F. J. Lewis: G.J., Vol. **24**, p. 273. 1904.
(241) Mems. G. S. Scot: Geology of Cowal. 1903.
(242) R. T. Günther: *op. cit.*
(243) P. Gnirs: quoted in G.J., Vol. **32**, p. 91. 1908.
(244) J. Frank: Petermann's Mitteil., July, 1913.
(245) J. Sion: Le Var Superieur. Paris. 1909.
(246) A. G. Högböm: Review in G.J., Vol. **38**, p. 422. 1911.
(247) A. G. Maddren: U.S.G.S. Bulletin 592.
(248) C. H. Clapp: *op. cit.*, p. 349.
(249) R. S. Tarr & L. Martin: U.S.G.S. P. P. 69. 1912.
(250) S. R. Capps: U.S.G.S. Bulletin 630, p. 83. 1916.
(251) A. C. Lawson: U.S.A. Geologic Atlas. Fol. 193, p. 20. 1914.
(252) E. Wittich: G.J., Vol. **40**, p. 89. 1912.
(253) J. W. Gregory: G.J., Vol. **34**, p. 294. 1909.
(254) A. Deussen: U.S.G.S. Water Supply Paper 335. 1914.
(255) L. W. Collet: Structure of the Alps, p. 145. London. 1927.
(256) A. P. Coleman: Ice Ages, Recent and Ancient. 1926.
(257) M. Boule: Fossil Men. Edinburgh. 1923.

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